II HYDROLOGIC MODEL DEVELOPMENT

This section will contain several discussions regarding the description, modifications to, and assumptions used in the development and execution of the hydrologic simulation model used in this investigation.

A. HYDROLOGIC MODEL DESCRIPTION (HYDROSS)

A river operation simulation model, using streamflows that occurred during the critical drought period of the 1930s and for the period following through 1984, was used to estimate the conditions for the future municipal, rural, and industrial water supplies in the Red River of the North Basin. The computational base for simulation was the Hydrologic River Operation Study System (HYDROSS) program. HYDROSS was originally developed by the Bureau of Reclamation (Reclamation) in 1977 as a surface water supply model to evaluate existing and proposed demands on a river system. The model is intended to operate over the period of record, simulating the effect of the existing and proposed features on the basin natural flows (Reclamation, 1991).

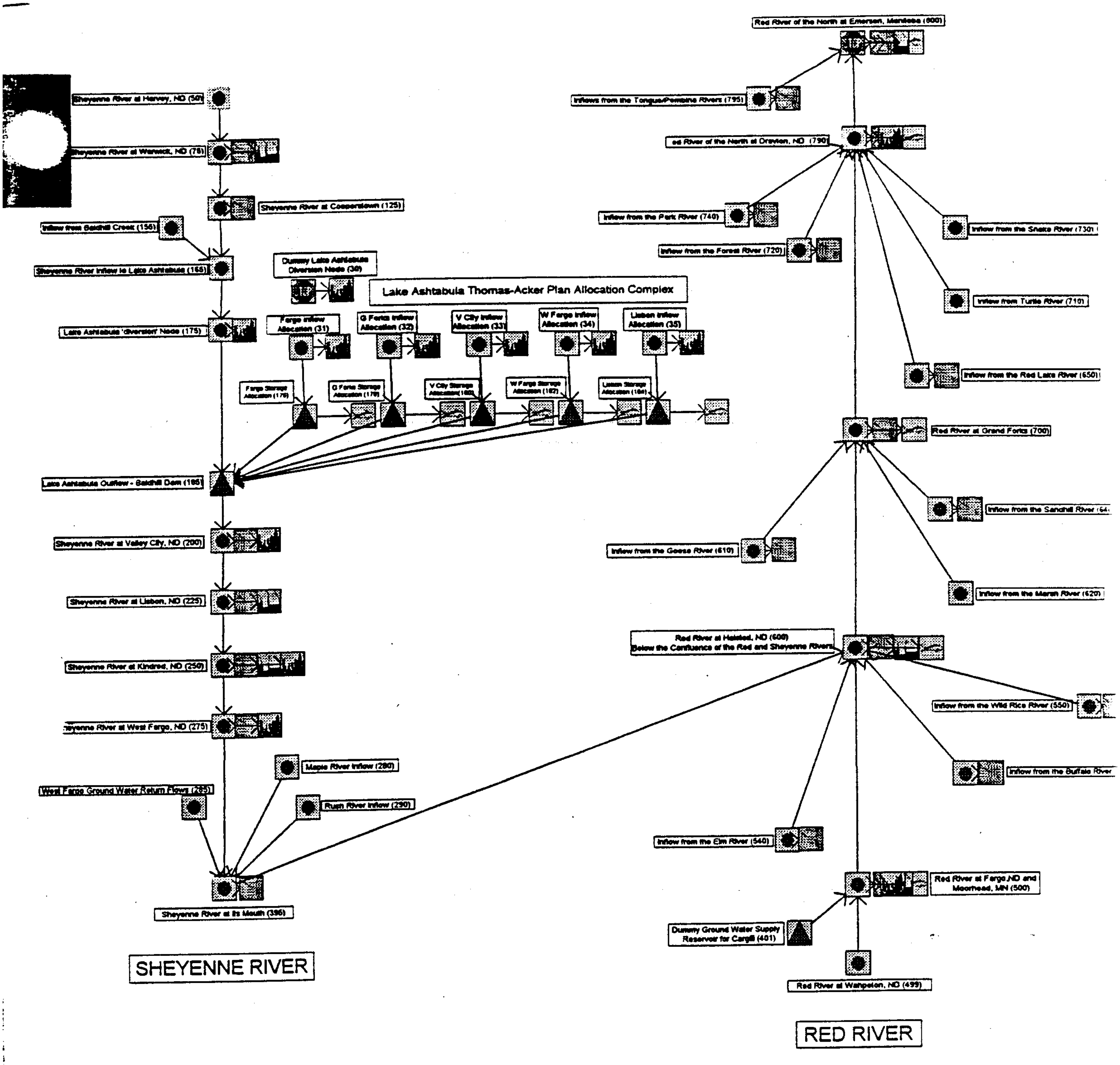
The simulation period in this study is from 1931 to 1984 using natural flows computed by U.S. Geological Survey (USGS) in 1991 (Guenther et al., 1991). The water study is based on monthly flows from the 1931-84 period with projected future (year 2050) demands placed on the river. Flows and demands are computed on a volumetric basis. The use of this model with monthly volumetric data is typical of many planning studies.

The purpose of the modeling component is to determine if the existing sources of water are adequate to meet future municipal, rural, and industrial demands during a critical drought period. Shortages that occur represent demands for water that will need to be supplied from other sources. The duration of shortages and quantity of demand will be used in future studies to develop an alternative for managing future water supplies. A listing of assumptions used as a part of the modeling effort can be found later in this chapter.

In addition to demand and water rights data, reservoir operations, including capacity reduction by sedimentation and net evaporation were also considered. A schematic of the river operation study is shown on Figure 2. Tables 1 and 2 list the model nodes shown in the schematic for the Sheyenne and Red Rivers, respectively.

It should be noted that this study was done at an appraisal level of detail which will provide results showing the general magnitude and trends of water shortages. Several assumptions were used in the development of demands and operation of the river system. If more detailed studies are desired at a later date, the HYDROSS model input can be refined to a much more detailed level. Because the appraisal level of detail was used in this effort, both strengths and weaknesses to the model setup must be noted.

Strengths of the HYDROSS model over past methods Reclamation used include the ability of the model to base demands on water right priority. This allows the modeler to trace shortages to individual rights if necessary and presents a more realistic picture of demand patterns throughout the basin. Also, the concepts of "project" or stored water versus "natural" flow water can be segregated throughout the river flow system.



Legend

- Flow Node/Reservoir Node
- Municipal Diversion
- Industrial Diversion
- Irrigation Diversion
- Ashtabula Operational Release

Figure 2

General Schematic of HYDROSS Model Structure of the Red River Valley (2050 Baseline)

Table 1: HYDROSS Model Node Description of the Sheyenne River

Station Node	Sheyenne River HYDROSS Node Description
50	Sheyenne River at Harvey, North Dakota
75	Sheyenne River at Warwick, North Dakota
125	Sheyenne River at Cooperstown, North Dakota
155	Baldhill Creek Inflow, North Dakota
165	Sheyenne River Inflow to Lake Ashtabula, North Dakota
175 176 178 180 182 184	Lake Ashtabula Diversion node 30 - Node 31 Fargo Inflow Allocation - Node 32 Grand Forks Inflow Allocation - Node 33 Valley City Inflow Allocation - Node 34 West Fargo Inflow Allocation - Node 35 Lisbon Inflow Allocation
185	Lake Ashtabula Outflow
200	Sheyenne River at Valley City, North Dakota
225	Sheyenne River at Lisbon, North Dakota
250	Sheyenne River at Kindred, North Dakota
275	Sheyenne River at West Fargo, North Dakota
280	Maple River Inflow in North Dakota
285	West Fargo ground water return flow
290	Rush River Inflow in North Dakota
395	Sheyenne River at its mouth in North Dakota

Table 2: HYDROSS Model Node Description of the Red River

Station Node	Red River HYDROSS Node Description
Upper Red River	
401	Dummy ground water supply reservoir for Cargill in North Dakota
499	Red River at Wahpeton, North Dakota
500	Red River at Fargo, North Dakota
525	Inflow from Buffalo River in Minnesota
540	Inflow from the Elm River in North Dakota
550	Inflow from Wild Rice River in Minnesota
Lower Red River	
600	Red River at Halstad, Minn. below confluence of Red and Sheyenne River
610	Inflow from Goose River in North Dakota
620	Inflow from Marsh River in Minnesota
640	Inflow from the Sandhill River in Minnesota
650	Inflow from the Red Lake River in Minnesota
700	Red River at Grand Forks, North Dakota
710	Inflow from Turtle River in North Dakota
720	Inflow from the Forest River in North Dakota
730	Inflow from the Snake River in Minnesota
790	Red River at Drayton, North Dakota
795	Inflow from the Tongue and Pembina River in North Dakota
800	Red River at Emerson, Manitoba

Because USGS flow data were available, the additional period of record allowed analysis to be performed on other dry periods that occurred since the early 1930s. One weakness of the HYDROSS model is that it is set up to operate on a monthly time step. This is considered more than adequate for planning purposes at an appraisal level of study; however, it must be emphasized that monthly data do not fully represent peak use periods that occur on a day-to-day basis. In addition, return flows from demands are restricted to monthly time-step patterns of return.

Several other factors regarding this modeling effort should be considered when reviewing the results presented in the following sections. A summary of these factors is listed below with more detail provided in the following sections.

1. It must be stressed that this effort was set at an appraisal level of detail. More detail can be added to the model if future studies are desired.

2. Demand and depletion data for the Minnesota side of the Red River Basin were limited in scope due to the focus of this study being within North Dakota. It is suggested that any future comprehensive study include full detail regarding Minnesota water resources.

3. Certain industrial and miscellaneous uses were kept at full water right (if no detailed information was available). These uses and their respective actual depletions would need further analysis in subsequent studies.

4. An increment of additional industrial demand was included in the modeling in the form of four additional Cargill type corn processing plants located near Kindred, Abercrombie, Fargo, and Drayton. These are intensive water using centers and may not actually represent potential industrial growth. In fact, these plants may be an overestimation of additional industrial demands in the basin. The placement and inclusion of these reports represents speculation of future demands agreed to by the Steering Committee and are not backed by a detailed demand analysis. It is recommended future studies explore this aspect of future demand in greater detail.

5. Detail on depletions from uses on tributaries of the Sheyenne and Red Rivers was based on the USGS 1991 study. This procedure was deemed adequate for this level of study; however, subsequent studies should include more detail regarding tributary depletions.

6. Lakes Traverse and Orwell and the Red Lakes were treated as being a part of input of depleted flows to the upper areas of the Red River model. Again, if more detailed investigations are desired, full detailed operations should be considered.

7. Lake Ashtabula operations were included in this study; however, minimum reservoir levels were maintained at elevation 1257 (a capacity of 30,100 and 28,000 acre-feet in the years 1994 and 2050, respectively, as a result of sediment inflow) to account for fish and wildlife uses. In future studies that look into alternative plans, a closer look at this type of operation, including testing of drought operation criteria, is suggested. It should be noted that any shortage that was computed regarding the Lake Ashtabula shortage was

distributed among the five cities currently holding permits to that storage (see the “Lake Ashtabula Operations" section for more detail).

8. Throughout the basin, it is known that some gain and loss reaches exist along the Sheyenne and Red Rivers. In addition, it is expected that some losses occur due to evaporation. The general assumption used in this study was that the USGS computed natural flows did account for most of these natural gains and losses. Operational losses, in the reach below Lake Ashtabula and the Red River confluence with the Sheyenne River, were included based on general information and assumptions. These loss assumptions, however, may need further refinement if a more critical level of detail is desired.

9. The results of the model simulations should be interpreted with care regarding climatic conditions. For example, the two years with high levels of shortages based on the model results were 1934 and 1936. From about 1929 to 1942, streamflow deficits in rivers throughout the State defined a less than normal trend that indicates a drought. Only partial records are available for that period at most gauging stations. However, available streamflow records throughout the State during this period indicate that this drought had a recurrence interval that exceeded 25 years. The drought was most severe from 1929 to 1936; drought conditions moderated in parts of the state in 1937 and 1938. The drought may have been the most severe through 1934 - - the sixth consecutive year that precipitation had been less than normal and the driest year on record (USGS WSP 2375 (1988-89). Although both years were very dry for the entire basin, shortages in some portions of the basin varied because of the effect of localized thunderstorms. As an example, 1934 revealed slightly drier conditions in the Sheyenne River drainage, and 1936 demonstrated slightly drier conditions in the Red River. In order to provide some degree of relative comparison, an effort was made to define what a wet, normal (average), and dry year was in the study area. The interpretation of shortage patterns in these years could then add to the detail of the discussion of results. However, the inclusion of the shortage patterns as discussed for dry, normal, and wet years should be viewed with caution because the results obtained in these years depend on localized events and antecedent (previous year) conditions (i.e., a dry year preceded by a wet year may not fully represent “dry” conditions). For purposes of this study, the following generalizations were made regarding shortages in dry, normal, and wet year conditions. To meet the conditions below, each year had to satisfy criteria for precipitation gages located at Lake Ashtabula, Wahpeton, and Grand Forks. These stations were chosen so as to represent the Sheyenne River, the upper Red River, and the lower Red River portions of the study area.

a. Dry years were generally considered represented by conditions observed from the years 1933 through 1940. These years were all generally the driest on record. For purposes of this study, the total annual precipitation for each year (1931 to 1984) was ranked from highest to lowest. A year that experienced an annual precipitation amount less than the 25th percentile of the ranked annual precipitation for each of the three precipitation stations (about ½ of the standard deviation of the average annual precipitation for the 1931 to 1984 period) was considered a dry year *if* the preceding year also fit the same criteria. Only one year fell into this category: 1934. Several other years in the period of record were also very dry, but they did not fully meet these criteria.

b. Wet years were generally considered to be years when the precipitation was greater than the 75th percentile of the ranked annual precipitation recorded from 1931 through 1984 using the same methodology discussed above. In addition, to qualify as a wet year, the preceding year also had to have met the same criteria. None of the years actually met these criteria for all three gauges. However, the year 1965 was generally considered wet for all three portions of the study area, and came close to meeting these criteria.

c. Normal years were years in which the total annual precipitation fell between the 25th and 75th percentile of the 1931 through 1984 ranked annual precipitation using the same methodology described above. To “qualify” as a normal year, the preceding year must have also met the same criteria. One year met these criteria for all three stations: 1984.

d. All other years represented a combination of wet/dry year conditions.

The analysis used to examine shortage patterns for the dry, normal, and wet year is general in nature. Other factors that can affect the shortage distribution are irrigation levels and the level of storage in Lake Ashtabula. For example, in 1940, Lake Ashtabula storage levels were nearly depleted after the 1930s drought. This drought created large shortages because of a limited “cushion” of storage water.

Considering the above items, by Reclamation standards, this study is considered more than adequate for the appraisal level of detail. The model did provide detail on the most critical demands, operations, return flows, and gains and losses of the river system. Usually in this level of study, modeling is used to determine general magnitude and trend of shortages. M&I water supply plans usually include "dry" years as the criteria for determining water supply facilities. Water supply facilities need to be viable for same type of "dry" or drought condition and still deliver water under some type of peak daily demand.

The HYDROSS modeling did indeed provide a good indication of shortage magnitude for present and year 2050 conditions. In addition, detail regarding individual city and water right shortages was provided.

Other considerations regarding the data used in this study's modeling are discussed in the following sections.

B. HYDROLOGIC MODEL PHASE I, PART A TO PHASE II MODIFICATIONS

Since the completion of the Phase I, Part A, Red River Valley Water Needs Assessment study, several improvements and modifications to the hydrologic modeling have occurred. These changes will be displayed in the Phase II report due later this year. This briefing will describe the changes being made and discuss the expected impact on previously reported results. A comparison of Phase I and expected Phase II Baseline simulation shortages for the participating cities are displayed in Table 3.

1. Phase II Modifications:

a. *HYDROSS Model Upgrade:* The version of HYDROSS used in Phase I has been upgraded to the current version as of August 1998. The newer version allows for shifts between primary and supplemental rights, better reservoir balancing, and a more detailed description of water right priority dates. The new program also distinguishes priority dates of water rights by month/day/year rather than just by year as in the older version.

b. *Fargo-Moorhead Demand/Return Flow Changes:*

1. *Recompilation of the city of Fargo's 2050 demands:* Due to a misinterpretation of raw versus treated water demand, it was agreed to change Fargo's raw water demand to 36,610 acre-feet per year from 44,455 acre-feet per year. This resulted in a change of per capita use from 206 to 170 (rounded up from 166) gallons per capita per day. This agreed upon change was confirmed in a conference call on June 5, 1998, between representatives of the City of Fargo, Reclamation, Senator Conrad's office, Senator Dorgan's Office, the North Dakota State Engineer, and the Garrison Diversion Conservancy District.

2. *Repositioning the Moorhead diversion to directly upstream of the Fargo diversion:* As a result of comments from the city of Moorhead, MN, an effort was made to better understand the modeled split of shortages between the two cities. Several model runs were made to determine if an improvement in modeling framework could be made at this locale. Discussions with Cliff McClain, Moorhead Public Service, also took place in this effort. As a result, the following change was made: It was determined that repositioning the Moorhead diversion to directly upstream of the Fargo diversion would give the city of Moorhead a subtle priority in diversion position over Fargo. This change was made in recognition that Moorhead is in a Riparian Water Doctrine state and over two-thirds of the inflow to the Red River originates from the Minnesota side of the Valley. The result of this change was to slightly reduce Moorhead's surface water shortages.

3. *Repositioning the return flow point of both Fargo and Moorhead to the next model node downstream:* It was determined through further testing that since both cities had diversions and return flows in the same model node, the downstream city (Fargo) was unrealistically benefitting from Moorhead return flows. This was a significant change which caused Fargo's shortages to increase significantly as a result of the volume of return flows involved.

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Table 3
Comparison of Greatest Annual Shortage
Between Phase IA 2050 Baseline HYDROSS Simulation and
Simulation with Phase II Modifications

City	Original Phase IA Result (AC-FT/YR)	Phase II Result (AC-FT/YR)
Drayton	60	60
East Grand Forks	0	0
Fargo	4,892	25,330
Grafton	290	290
Grand Forks	2,729	0
Lisbon	52	90
Moorhead	5,410	5,360
Valley City	916	430
West Fargo	131	149

Note: Wahpeton and Breckenridge not included as both cities rely on ground water supplies.

Explanation of Results:

1. **Drayton:** Drayton's shortages remained the same. Drayton has a water right senior and junior to both Fargo and Grand Forks and no Lake Ashtabula storage allocation, so a shortage occurred during the most critical dry month of the simulation.
2. **East Grand Forks:** Due to its location on the Red Lake River, Phase II modifications had no effect on this city's shortages.
3. **Fargo:** The result of the change in return flow location for Moorhead greatly increased Fargo's dependency on Lake Ashtabula water thus resulting in a much higher level of shortages during the prolonged 1930's drought. The removal of Moorhead and Fargo returns from the node of their diversions meant a significant reduction in modeled supply. This was considered the most significant change in the model.
4. **Grafton**: No change. The Grafton shortage was still during the most critical dry month of the year.
5. **Grand Forks:** Grand Forks shortages were offset by the repositioning of its own and East Grand Forks return flows and by the advantage of more return flow being available from the Fargo-Moorhead return flow shift. Grand Forks shortages is placed against Lake Ashtabula.
6. **Lisbon:** Lisbon's shortages increased as a result of the increased demand on Sheyenne River water due to the shift in Fargo's return flow positioning (which increased West Fargo needs). In addition, since the newer version of HYDROSS allowed for more detailed priority dates (day/month/year), Fargo received an advantage in priority.
7. **Moorhead:** As a result of repositioning Moorhead's diversions and return flows, the city received a slight advantage of diverting water over Fargo. Hence, the city's shortage was reduced.
8. **Valley City:** Valley City's shortages decreased due to the removal of all instream flow data from the program and because the Lake Ashtabula segregation into city allocations (based on the Thomas-Acker Plan). The Lake Ashtabula change in the model allowed Valley City to receive its full allocation in most years thereby reducing its shortage level.
9. **West Fargo:** West Fargo's shortages showed an slight increase due to the repositioning of Fargo's Sheyenne River return flows (from Lake Ashtabula diversions) to a point further downstream thus increasing West Fargo's dependence on the Sheyenne River and Lake Ashtabula. Sensitivity runs of the model indicated that West Fargo was unrealistically benefitting from return flows from the Fargo diversion point.

4. *Repositioning the return flows of the city of Fargo diverted on the Sheyenne River (from Lake Ashtabula) to the same downstream point as in item "2" above:* The original positioning of these return flows was at the confluence of the Red and Sheyenne Rivers. What was actually happening was that a portion of the return flows were being routed down the lower Sheyenne rather than in the Red River allowing West Fargo to unrealistically receive some benefit from the returns. In actuality the repositioning of these return flows had only minor effects.

c. *Repositioning of the return flows from Grand Forks and East Grand Forks to the next node downstream:* This change was done as a result of the observations during the Fargo-Moorhead return flow modification in item "2" above. This improved the reality of the modeling so neither city would benefit from the others return flows.

d. *Improvement of Simulation of the Existing Cargill (ProGold) plant near Wahpeton:* This improvement consisted of adding a ground water use scenario based on the North Dakota State Water Commission permit for the plant. Some ability to reuse water was also included. These changes were based on conversations with Craig Maetzold of the Cargill Company and Craig Odenbach of the State Water Commission.

e. *Removal of all instream flow needs/Monitoring:* Although instream flows were not being considered in Phase I, Part A monitoring of instream flow levels was included on both the Red and Sheyenne Rivers as a low level priority. As a result of this, Lake Ashtabula may have attempted to meet these low level flows in years with available water. The flow points were zeroed in the model to prevent this from happening. It was assumed that this would only have a negligible effect on results.

f. *Improvement of the Lake Ashtabula Thomas-Acker Plan Shortage Distribution:* A simplified computation of redistribution of shortages for the five cities (Fargo, West Fargo, Grand Forks, Valley City, and Lisbon) receiving water from Lake Ashtabula was used in Phase I, Part A. However, with the increase in shortages expected as a result of changes in Phase II, this method of computation was deemed inadequate. As a result, an attempt to make the model more accurate and automatic for distributing shortages as per the Thomas-Acker Plan was accomplished. The Thomas Acker Plan is a storage allocation agreement between Fargo, Grand Forks, Valley City, West Fargo, Lisbon and the Corps of Engineers. The agreement is further explained in the Assumptions section under the “Lake Ashtabula Operations” subsection. The agreement is further described in a memorandum dated November 27, 1992 from the Director of the Hydrology Division to a Water Resource Engineer assigned to the State Water Commission. A copy of this memorandum is located in Attachment I. Changes include splitting up the Lake Ashtabula contents, inflows, releases, and evaporation into six different operations. Lake Ashtabula was reorganized into 6 proportionally scaled down reservoirs that would operate to mimic the allocation to each city under the plan. The 6th reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option. Although not a perfect representation of shortage “faulting” of one or more city in one year that would affect the next year’s operation, this methodology provided a great improvement over Phase I computations.

C. MODEL ASSUMPTIONS

The following sections present the hydrologic model assumptions developed for this investigation regarding municipal, industrial, and rural water use projections, return flow scenarios, river and reservoir operations, channel losses, and irrigation practices occurring in the Red River Valley.

1. Water Use Projections

Future water use by cities as input to the HYDROSS model was based on a sector analysis of municipal and industrial (M&I) demands. The year 2050 was used to represent future conditions. Some demand data (primarily irrigation) was based on water right listings provided by the State of North Dakota. The water rights list in included as Attachment E. All water needs in regard to priority of water rights were also considered as part of the HYDROSS model input. Water use was projected separately for the residential, commercial, public, industrial, and rural sectors of the study area. These uses were also set by water right priority date in the model. Individual rights along the Sheyenne and Red Rivers were set at full value or modified per irrigation crop needs, conveyance, and onsite use efficiencies.

It should be pointed out that three sets of future demands were used in this study: Reclamation demand estimates for Phase I Part A, Reclamation demands for Phase II and Participant city demand estimates. The Phase II Reclamation demands supercede the Phase I Part A demands for Reclamation. Estimates for the city of Fargo changed between the two phases of the study in terms of per capita use. Only the Phase II demands will be presented here. The Participant city demands remained the same for both phases of the study. The main differences between the year 2050 Reclamation and Participant demand estimates resulted from different population and per capita use projections. Some industrial uses also varied for some cities. Regarding the handling of water demands in the model, a variety of assumptions were used. Some basic assumptions and methods used are summarized below. Tables 4 through 7 list the annual and monthly M&I demands used by Reclamation and the participating cities under future conditions (present condition demands will be discussed later in this report).

The following lists general assumptions used for development of water use projections as used in the hydrologic model:

a. Demand estimates for residential, commercial, and public use were primarily based on Reclamation or Participant population and per capita use projections.

b. Industrial demand levels of each city were based on Reclamation industrial use projections. Reclamation used information provided by the cities. Also, the addition of Cargill or “new industrial” demand type industry (formerly refereed to as ProGold2 through ProGold5 in the Phase I, Part A report) were used to represent increased agricultural processing industrial use in the study area.

Table 4: Red River valley water Needs Assessment
Future Condition (2050) Population and Municipal and Industrial Water Use: Reclamation Projections

File: Dem94-50.wk4 v. 6/20/98

Municipality		2050 Population	SURFACE WATER DEMANDS: Residential Commercial & Public use (gpc/d)	Residential Commercial & Public use (acre-feet)	Industrial use (gpc/d)	Industrial use (acre-feet)	TOTAL (Comm,Public & Industrial DEMAND (gpc/d)	TOTAL (Comm,Public & Industrial DEMAND (acre-feet)	GROUND WATER: TOTAL DEMAND (gpc/d)	GROUND WATER: TOTAL DEMAND (acre-feet)	TOTAL SURFACE (BEFORE LOSSES): TOTAL DEMAND (gpc/d)	TOTAL SURFACE (BEFORE LOSSES): TOTAL DEMAND (acre-feet)	CITY LOSS RATE (%)	RAW WATER DEMANDS (SURFACE SUPPLY ONLY): TOTAL DEMAND (acre-feet)	RAW WATER DEMANDS (SURFACE SUPPLY ONLY): TOTAL DEMAND (gpc/d)
Fargo	1	192,600	131	28262	9	1942 1	140	30204	0	0	140	30204	17.5 2	36610	170
West Fargo	4,16	33,300	120	4476	18	657 14	138	5133	76	2823 11	138	5133	10.0 3	5703	153
Moorhead, MN	4,10,17	42,600	120	5726	48	2300 14	168	8026	14	662 11	168	8026	10.0 3	8918	187
Valley City	5	6,570	105	773	49	357 14	154	1130	0	0	154	1130	10.0 3	1255	171
Grand Forks	6	93,200	100	10440	93	9740 14	193	20180	0	0	193	20180	15.0 3	23741	227
East Grand Forks	7	8,700	120	1169	21	200 14	141	1369	0	0	141	1369	20.0 3	1712	176
Grafton	8	5,100	120	686	76	432 14	196	1118	0	0	196	1118	10.0 3	1242	217
Drayton	9	900	120	121	519	523 15	639	644	0	0	639	644	15.0 3	758	752
Wahpeton		9,200	0	0	0	0	0	0	137	1410 11	0	0	20.0 3	0	0
Breckenridge, MN		3,700	0	0	0	0	0	0	140	580 11	0	0	20.0 3	0	0
Existing ProGold	12	-	-	-	-	6,000	-	6,000 -	-	0	-	-	- -	6,000	-
Future "ProGolds"	12,13	-	-	-	-	24,000	-	24,000 -	-	0	-	-	- -	24,000	-
TOTALS:		395,870		51,653		46,151		97,803		5,475		67,803		109,939	

1. Detailed sector use was not available from the city. Early in this study, the 2040 level of use was used for future conditions. Fargo's 2040 demand included 5% industry (USCOE, 1985). This 2040 demand was extended to the year 2050 by using the same 2040 commercial, residential and public use rate modified by population. Industrial growth was extended to 2050 by maintaining the same 5% level of total use used in the 2040 p Additional industrial growth was also considered for the city in the form of a "ProGold" type plant. This plant, designated ProGold2, was placed within 10 miles of the city on its own water supply and water right - it is not included in the Fargo demand estimate above. *Also refer to* notes 12 and 13 regarding "ProGold" type plants.
2. Fargo's loss was estimated at 17.5 percent which represents the 1990 - 1994 average.
3. Use rates vs projected raw water demand are based on the 1994 estimate of system *losses rounded to a percent loss rate from 10 to 20% (high: 20%, medium: 15%,* or low. 10%) of the surface water diversion. The difference between the billed amount and the diversion amount allows for treatment plant operations such as filter backwashing, and other miscellaneous losses.
4. *The use rate for future conditions was set at 120 gpc/d for commercial, domestic and public use. This was based on a combination of* Reclamation Planning instruction 82-01 dated 1/15/82, and projected use rates for other cities such as Winnipeg, Manitoba which forecasts a use rate of 119 gpc/d for the city. The level of 120 gpc/d is considered to be viable based on professional judgement.
5. *The current use rate provided by Valley City was originally set at 104 gpc/d for 1994.* Reclamation adjusted this amount to 105 gpc/d commercial and public use based on Planning instruction 82-01.
6. The level of demand for 2040 was based on the report "50 Year Water Quanity and Needs Study for the City of Grand Forks by Advanced Engineering - Draft p105-02.11). The city advised Reclamation that the 100 gpc/d estimate was based on the city's best estimate of conservation. Projections were extended to 2050 by population changes and a straight line extension of the 2025 to 2040 industrial use.
7. East Grand Forks industrial projections by the participant assumed that American Crystal Sugar may expand. Because the future business plans by American Crystal Sugar are uncertain, and that they may remain within existing rights (all other rights for this company held at full for modeling purposes), it was decided to keep the current level of water use for this company for future modeling scenarios. Also, some of the additional "ProGold" type plants added to the basin model in the future scenarios were assumed to cover some of this potential expansion. Also refer to notes 12 and 13 regarding "ProGold" type plants.
8. City of Grafton industrial use for 2040 based on a letter from Advanced Engineering dated 1/02/95. The letter projects an increase of 30% for Alchem and 35% for other users totaling 432 af/yr. Projections were extended to 2050 by population increases and extension of the 2025 to 2040 industrial use trend.
9. Drayton industrial use based on city estimates minus a city estimate of 750,000,000 gallons per year "other" use. The elimination of this level of industrial use was primarily done due to lack of evidence of this use in future city projections.
10. Moorhead industrial use set based on comments provided by the city to first draft report concerned with this study.
11. Groundwater Use set by Participant input. Not used in HYDROSS surface water model.
12. Each ProGold entered into the Red River of the North Basin is assumed to represent a total diversion of 6000 acre-feet per year with 3000 acre-feet of consumed water.
13. *Industrial development in the Red River Valley has the potential to grow. The type of industrial growth with the greatest potential is the food processing industry.* For modelling purposes this growth was expressed in "ProGold Units" (potential growth expressed as future ProGold plants sized for a demand of 6,000 af/yr per plant) These plants were distributed in the Valley based on results of Reclamation's economic analysis. In the model these are designated as ProGold2, ProGold3, *ProGold4 and ProGold5. ProGold1 is the existing plant.*
14. Industrial growth for the cities were indexed from the original 2040 demand estimates by a straight line method accounting for the growth from 2025 to 2040 then extended to the year 2050.
15. *City of Drayton industrial use projections were* based on estimates provided by Advanced Engineering (AE) (letter dated 2/9/95) for American Crystal Sugar and a full sized plant for Drayton Grain Processors. Estimates for other projected industries provided by AE were not used based on a discussion with Steve Burian of AE due to the placement of a "ProGold unit" of new industry in the vicinity of Drayton.
16. City of West Fargo's ground water demand held constant from 1994. All future demands since 1994 were assumed to be supplied by surface water.
17. The city of Moorhead did not derive any of its supply from Lake Ashtabula. Future studies may require a tailoring of the model to better reflect segregation of Moorhead and Fargo shortages.

Table 5: Red River Valley Water Needs Assessment File: RRD50.WK4 Corresponds with DEM94-50.wk4 dated 1/9/97

2050 Conditions Reclamation City Projection Monthly Demand Summary (Units = 1000s acft/month)

DEMAND BREAKDOWN BY MODEL DIVERSION NUMBER AND MODEL WATER RIGHT DESIGNATION															MAXIMUM ALLOWED BY WATER RIGHT
City/User (d=diversion no.)	Priority Date	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	
700 VALLEY CITY															
d991	1963	89.1	97.9	105.4	104.2	118.0	131.8	114.2	106.7	102.9	97.9	92.9	94.1	1255.0	6686
710 LISBON															
d992	1982	26.5	29.1	31.3	31.0	35.1	39.2	33.9	31.7	30.6	29.1	27.6	28.0	373.0	373.0
d710	1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Dummy
720 FARGO															
d104 (non strge)	1957	2599.3	2855.6	3075.2	3038.6	3441.3	3844.1	3331.5	3111.9	3002.0	2855.6	2709.1	2745.8	36610.0	109500
730 WEST FARGO															
d049	1918	14.2	15.6	16.8	16.6	18.8	21.0	18.2	17.0	16.4	15.6	14.8	15.0	200.0	200.0
d996	1963	219.3	240.9	259.5	256.4	290.4	324.3	281.1	262.6	253.3	240.9	228.6	231.7	3089.0	35880.0
d994	1961	67.7	74.4	80.1	79.2	89.7	100.2	86.8	81.1	78.2	74.4	70.6	71.6	954.0	954.0
d995	1961	103.7	113.9	122.6	121.2	137.2	153.3	132.9	124.1	119.7	113.9	108.0	109.5	1460.0	1460.0
													TTL:	5703.0	
800 MOORHEAD															
d800	N/A	633.2	695.6	749.1	740.2	838.3	936.4	811.5	758.0	731.3	695.6	659.9	668.9	8918.0	Dummy
740 GRAND FORKS															
d128	1960	1780.6	1756.8	1804.3	1804.3	2089.2	2160.4	1946.8	2397.8	2112.9	2089.2	1875.5	1923.0	23741.0	33600.0
810 EAST GRAND FORKS															
d810	N/A	128.4	126.7	130.1	130.1	150.7	155.8	140.4	172.9	152.4	150.7	135.2	138.7	1712.0	Dummy
750 GRAFTON															
d144	1961	88.2	96.9	104.3	103.1	116.7	130.4	113.0	105.6	101.8	96.9	91.9	93.2	1242.0	1296.6
760 DRAYTON															
d149	1956	53.8	59.1	63.7	62.9	71.3	79.6	69.0	64.4	62.2	59.1	56.1	56.9	758.0	5100.0
770 PEMBINA															
d164	1989	6.1	6.7	7.2	7.1	8.1	9.0	7.8	7.3	7.1	6.7	6.4	6.5	86.0	154.0

Notes:
1. Moorhead and East Grand Forks are located in a Riparian Doctrine water law state. A dummy water right was assigned to this city with a priority date 1 day senior to Fargo's water right date.
2. The existing and "proposed" four Cargill Plants near Wahpeton was assumed to have a constant demand of 500 acre-feet per month (6000 acre-feet per year).
5. Diversion numbers are model designations only. Actual permit numbers can be found in Attachment ~~K~~ E.

Table 6: Red Riv... ...ey water Needs Assessment **FINAL** File: Dem94-50.wk4 v. 1/9/97

Future Condition (2050) Population and Municipal and Industrial Water Use: Participant Projections

Municipality	2050 Population	SURFACE WATER DEMANDS: Residential Commercial & Public use (gpc/d)	Residential Commercial & Public use (acre-feet)	Industrial use (gpc/d)	Industrial use (acre-feet)	TOTAL (Comm,Public & Industrial DEMAND (gpc/d)	TOTAL (Comm,Public & Industrial DEMAND (acre-feet)	GROUND WATER: TOTAL DEMAND (gpc/d)	TOTAL DEMAND (acre-feet)	TOTAL SURFACE (BEFORE LOSSES): TOTAL DEMAND (gpc/d)	TOTAL DEMAND (acre-feet)	CITY LOSS RATE (%)	RAW WATER DEMAND (SURFACE SUPPLY ONLY): TOTAL DEMAND (acre-feet)	TOTAL DEMAND (gpc/d)
Fargo	243,072 [1,16]	193	52606	10	2769 [14]	203	55375	0	0	203	55375	17.5 [2]	67122	247 [2]
West Fargo [4,17]	28,050 [9,16]	120	3770	21	657 [14]	141	4427	90	2823 [11]	141	4427	10.0 [3]	4919	157
Moorhead, MN [4,10,18]	42,358 [9,16]	120	5694	48	2300 [14]	168	7994	14	662 [11]	168	7994	10.0 [3]	8882	187
Valley City [5]	10,923 [9,16]	105	1285	29	357 [14]	134	1642	0	0	134	1642	10.0 [3]	1824	149
Grand Forks [6]	98,339 [9,16]	100	11015	88	9740 [14]	188	20755	0	0	188	20755	15.0 [3]	24418	222
East Grand Forks [7]	9,013 [9,10,16]	120	1212	20	200 [14]	140	1412	0	0	140	1412	20.0 [3]	1764	175
Grafton [8]	7,416 [9,16]	120	997	52	432 [14]	172	1429	0	0	172	1429	10.0 [3]	1588	191
Drayton	1,380 [9,16]	120	185	2155	3331 [15]	2275	3516	0	0	2275	3516	15.0 [3]	4137	2676
Wahpeton	9,207 [9,10,16]	0	0	0	0	0	0	137	1410 [11]	0	0	20.0 [3]	0	0
Breckenridge, MN	3,682 [9,10,16]	0	0	0	0	0	0	141	580 [11]	0	0	20.0 [3]	0	0
Existing ProGold [12]	-	-	-	-	6,000	-	6,000 -	-	0	-	-	- -	6,000	-
Future "ProGolds" [12,13]	-	-	-	-	24,000	-	24,000 -	-	0	-	-	- -	24,000	-
TOTALS:	453,440		76,764		49,786		128,550		5,475		96,550		144,654	

1. Fargo's 2050 demand based on population and per capita use provided in letter to the ND State Engineer from the Mayor of Fargo dated 12/23/94. The 17.5 percent ***loss rate was determined as an average annual loss rate for system losses and treatment plant operations. This loss was included in demand rate provided in the cited letter*** **(Pat Zavoral, City of Fargo, personal communication). Additional industrial growth in the Fargo area was also considered for the city in the form of a "ProGold" type plant. This plant, designated ProGold2** was placed within 10 miles of the city on its own water right. Also refer to notes 12 and 13 regarding other "ProGold" type plants.
2. Fargo's loss was estimated at 17.5 percent which represents the 1990 - 1994 average. **Because this is an estimated value, the original total demand *estimated by Fargo (67,075 acre-feet) was increased by 47 acre-feet to maintain the 247 gpc/d estimated by the city.***
3. Use rates vs projected raw water demand are based on the 1994 estimate of system losses rounded to a percent loss rate from 10 to 20% (high: 20%, medium: 15%, or low: 10%) of the surface water diversion. The difference between the billed amount and the diversion amount allows for treatment plant operations such as filter backwashing, and other miscellaneous losses.
4. The use rate for future conditions was set at 120 gpc/d for commercial, domestic and public use. This was based on a combination of Reclamation Planning instruction 82-01 dated 1/15/82, and projected use rates for other cities such as Winnipeg, Manitoba which forecasts a use rate of 119 gpc/d for the city. The level of 120 gpc/d is considered to be viable based on professional judgement.
5. The current use rate provided by Valley City was originally set at 104 gpc/d for 1994. Reclamation adjusted this amount to 105 gpc/d commercial and public use based on Planning instruction 82-01.
6. The level of demand for 2040 was based on the report "50 Year Water Quanity and Needs Study for the City of Grand Forks by Advanced Engineering - Draft p105-02.11). The city advised Reclamation that the 100 gpc/d estimate was based on the city's best estimate of conservation. Projections were extended to 2050 by population changes and a straight line extension of the 2025 to 2040 industrial use.
7. East Grand Forks industrial projections by the participant assumed that American Crystal Sugar may expand. Because the future business plans by American Crystal Sugar are uncertain, and that they still have not fully used their existing water right to full capacity it was decided that for modeling purposes, to keep the current level of water use for this company for future modeling scenarios. Also, some of the additional "ProGold" type plants added to the basin model in the future scenarios were assumed to cover some of this potential industrial expansion.
8. City of Grafton industrial use for 2040 based on a letter from Advanced Engineering dated 1/02/95. The letter projects an increase of 30% for Alchem and 35% for other users totaling 432 af/yr. Projections were extended to 2050 by population increases and extension of the 2025 to 2040 participant industrial use trend.
9. Population projections were based on 2040 participant forecasts. These forecasts were modified to the 2050 level by a straight line extrapolation of the population growth trend from 1994 to the 2040 levels provided by the participants.
10. In some cases, Participant population projections were below Reclamation projections. When this occurred, the higher value was used.
11. Groundwater Use set by Participant input. Not used in HYDROSS surface water model.
12. Each ProGold entered into the Red River of the North Basin is assumed to represent a total diversion of 6000 acre-feet per year with 3000 acre-feet of consumed water.
13. Industrial development in the Red River Valley has the potential to grow. The type of industrial growth with the greatest potential is the food processing industry. For modeling purposes this growth was expressed in "ProGold Units" (potential growth expressed as future ProGold plants sized for a demand of 6,000 af/yr per plant). These plants were distributed in the Valley based on results of Reclamation's economic analysis. In the model these are designated as ProGold2, ProGold3, ProGold4 and ProGold5. ProGold1 is the existing plant.
14. Industrial growth for the cities were indexed from the original 2040 demand estimates by a straight line method accounting for the growth from 2025 to 2040 then extended to the year 2050.
15. Future industrial projections for the city of Drayton were based on estimates provided by Advanced Engineering (Steve Burian letter dated 2/9/95). These projections were assumed to represent all future conditions (out to the year 2050) by Reclamation's interpretation. It should be noted that Reclamation also included a "ProGold unit" of new industry near the city of Drayton on a separate water right.
16. Population for this city derived by a 10 year straight line growth extension of 1994 to Participant 2040 population estimates.
17. **City of West Fargo's ground water demand held constant from 1994. All future demands since 1994 were assumed to be supplied by surface water.**
18. **The city of Moorhead did not derive any of its supply from Lake Ashtabula. Future studies may require a tailoring of the model to better reflect segregation of Moorhead and Fargo shortages.**

Table 7: Red River Valley Water Needs Assessment File: RRD1994a.WK4 Corresponds with DEM94-50.wk4 dated 1/9/97

2050 Conditions Participant City Projection Monthly Demand Summary (Units = 1000s acft/month)

DEMAND BREAKDOWN BY MODEL DIVERSION NUMBER AND MODEL WATER RIGHT DESIGNATION

City/User (d=diversion no.)	Priority Date	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	MAXIMUM ALLOWED BY WATER RIGHT
700 VALLEY CITY															
d991	1963	129.5	142.3	153.2	151.4	171.5	191.5	166.0	155.0	149.6	142.3	135.0	136.8	1824.0	6686
710 LISBON															
d992	1982	26.5	29.1	31.3	31.0	35.1	39.2	33.9	31.7	30.6	29.1	27.6	28.0	373.0	373.0
d710	1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Dummy
720 FARGO															
d104 (non strge)	1957	4765.7	5235.5	5638.2	5571.1	6309.5	7047.8	6108.1	5705.4	5504.0	5235.5	4967.0	5034.1	67122.0	109500
730 WEST FARGO															
d049	1918	14.2	15.6	16.8	16.6	18.8	21.0	18.2	17.0	16.4	15.6	14.8	15.0	200.0	200.0
d996	1963	163.7	179.8	193.6	191.3	216.7	242.0	209.8	195.9	189.0	179.8	170.6	172.9	2305.0	35880.0
d994	1961	67.7	74.4	80.1	79.2	89.7	100.2	86.8	81.1	78.2	74.4	70.6	71.6	954.0	954.0
d995	1961	103.7	113.9	122.6	121.2	137.2	153.3	132.9	124.1	119.7	113.9	108.0	109.5	1460.0	1460.0
													TTL:	4919.0	
800 MOORHEAD															
d800	N/A	630.6	692.8	746.1	737.2	834.9	932.6	808.3	755.0	728.3	692.8	657.3	666.1	8882.0	Dummy
740 GRAND FORKS															
d128	1960	1831.3	1806.9	1855.8	1855.8	2148.8	2222.0	2002.3	2466.2	2173.2	2148.8	1929.0	1977.9	24418.0	33600.0
810 EAST GRAND FORKS															
d810	N/A	132.3	130.5	134.1	134.1	155.2	160.5	144.6	178.2	157.0	155.2	139.4	142.9	1764.0	Dummy
750 GRAFTON															
d144	1961	112.7	123.9	133.4	131.8	149.3	166.7	144.5	135.0	130.2	123.9	117.5	119.1	1588.0	1296.6
760 DRAYTON															
d149	1956	293.7	322.7	347.5	343.4	388.9	434.4	376.5	351.6	339.2	322.7	306.1	310.3	4137.0	5100.0
770 PEMBINA															
d164	1989	6.1	6.7	7.2	7.1	8.1	9.0	7.8	7.3	7.1	6.7	6.4	6.5	86.0	154.0

Notes:
1. Moorhead and East Grand Forks are located in a Riparian Doctrine water law state. A dummy water right was assigned to this city with a priority date 1 day senior to Fargo's water right date.
2. The existing and "proposed" four Cargill Plants near Wahpeton was assumed to have a constant demand of 500 acre-feet per month (6000 acre-feet per year)
5. Diversion numbers are model designations only. Actual permit numbers can be found in Attachment ~~H~~ E.

c. City demand priority was based on water right priority date. Water use was varied on a monthly basis during the year to consider both low, medium, and peak use periods. Priority for the City of Moorhead, MN, which operates under the Riparian Water Right Doctrine was set slightly ahead of Fargo, ND to ensure this city has priority due to quantity of natural flows originating in Minnesota.

d. Regarding Lake Ashtabula storage rights, shortages from storage demands were distributed among storage right holders as per the Thomas-Acker Plan (described in detail in the report), with the exception of maintaining a 28,000-acre-ft minimum pool. This was originally handled by a redistribution of shortages after model runs were complete in Phase I, Part A, however in Phase II the computation method was refined by splitting Lake Ashtabula into separate reservoirs to represent individual allocations for each city based on the Thomas-Acker Plan. This will be discussed in more detail in the "Lake Ashtabula Operations" section.

e. Estimated city loss rates were included for 2050 condition model runs. These rates were based on present condition data and were modified by grouping each city into high, medium, and low loss rate categories. The only exception to this was when demands representing a water conservation scenario were used in the model.

Other uses in the valley include irrigation, other industry, fish and wildlife, and smaller domestic uses (rural water systems). Some of the basic assumptions used for these sectors of water use were as follows:

a. Irrigation was included as a component of the hydrologic model. Irrigation water uses were maintained at 1994 levels and water right priority since future changes in irrigation practices were not within the scope of this study.

b. Miscellaneous industrial water use not aligned with city water systems was based on water right information. Satisfying these rights was attempted at full water right value dependent on the priority date of the right. Future condition scenarios maintained the current level of this water use. The one exception to this procedure was the assumption that additional industrial water use could come in the form of agricultural processing units similar to the existing Cargill plant. Industrial facilities such as this one could play a large part in the future water management of the basin. Four additional Cargill-type facilities were located in the study area to represent potential industrial growth in the year 2050.

c. The most critical component of water use for fish and wildlife was the maintenance of a minimum storage pool in Lake Ashtabula. For all model runs, Lake Ashtabula was restricted to a minimum elevation of 1257 feet above mean sea level for fish and wildlife purposes. The State of North Dakota does not recognize this minimum storage pool according to the Thomas-Acker Plan. However, the Corps does identify this minimum storage pool (elevation 1257 feet) in the Reservoir Regulation Manual (Corps, 1983).

d. Regarding rural water uses, little detail was available on future uses in these systems. Water demands in the rural areas of the Red River Basin are commonly met by using private individual wells or by connection to rural water systems. No future modeling scenarios were made for the rural sector and the rural water systems. However, a separate analysis of rural sections was completed and is discussed in the Phase II report.

Residential demand is water used at private living quarters such as single-family dwellings, apartments, condominiums, etc. Residential use includes sanitary and culinary in-house use as well as outdoor uses for lawn, garden, car washing, swimming pools, etc. Commercial demand includes water for retail and wholesale trade, motels and hotels, offices, hospitals, schools, restaurants, service establishments, etc. Public demand is that for fire protection, street washing, treatment plant usage, sewer flushing, parks, fountains, etc.

Industrial demands, which consist of all water used by manufacturing, energy conversion, and mining, are presented separately due to their importance.

Demands from irrigation were considered in this study. Data inputs to the HYDROSS model included water right acreage, crop consumptive use based on monthly climatic data, and crop types (three crops used: wheat, corn, and potatoes evenly distributed over each water right acreage). All future irrigation demands were set at 1994 levels. Since most irrigation utilized sprinklers, a water application conveyance efficiency of 90 percent and onsite efficiency of 85 percent were used in the model. The onsite efficiency figures were used based on information obtained from the North Dakota State Extension Service.

Other demands such as fish and wildlife water needs were taken into consideration based on existing water rights. Lake Ashtabula was kept above a minimum elevation of 1257 feet (approximately 28,000 acre-feet in capacity under future year 2050 conditions).

Rural demands included residential, commercial, and public water for the purposes described in the preceding paragraphs. Generally, a rural water supply system is any community or noncommunity system of water facilities established to provide piped water for human consumption, and has at least 15 service connections or regularly serves at least 25 individuals.

The January 15, 1982, Reclamation Technical Memorandum on Projection of M&I water supplies (Reclamation Planning Instruction No. 82-01, Technical Memorandum: Projection of M&I Water Demands dated September 15, 1982) indicates the M&I use in North Dakota to be 130 gallons per capita per day (gpc/d). *The Water Encyclopedia*, second edition, 1990, by Frits van der Leeden, Fred L. Troise, and David Keith Todd, shows the 1985 use in North Dakota to be 135 gpc/d. An additional source showing water use rates by State was the December 1994 *Opflow*, published by the American Water Works Association, which shows a use rate for North Dakota of 130 gpc/d.

The following average day M&I use breakdown in the Reclamation Planning Instruction No. 85-01 Technical Memorandum is presented as follows.

Residential use	90 gpc/d
Commercial use	24 gpc/d
Industrial use	10 gpc/d
Public use	6 gpc/d
-------------------------	--------------
Total M&I	130 gpc/d

Regarding peak daily use, the State's maximum (peak) day M&I use to average day M&I use ratio is estimated to be 1.85. For this study, the peak daily use was not included, however, monthly demand distribution estimates did account for different levels of water use throughout each year (see section "2.0 Monthly Demand Distribution" Tables 9 and 10). If more detailed studies are warranted, some adjustment of monthly values for peaking are recommended.

For several cities in this study, Reclamation used an estimate of 120 gpc/d for residential, commercial, and public use. Other rates were used for Valley City and Grand Forks based on data provided by the city. Industrial use rates were also based on information provided by these cities. The city of Fargo projected a much higher total use rate based on future industrial growth.

Reclamation developed a commercial, residential, and public rates for Fargo based on data provided by the city. Reclamation's industrial use rate for Fargo differed from the city's estimate due to the assumption that a portion of the industrial use may be on a separate water right near the city. This additional industrial use was modeled in the form of a new Cargill-type plant north of the city.

The amounts of water used by the city were modified to account for system losses. Each city provided Reclamation with estimated losses for present conditions. Reclamation then assumed that each city fell into a low, medium, and high category of system efficiency. Each city was then placed in a group based on their 1994 loss rate. These groups were designated as:

High	20 percent losses
Medium	15 percent losses
Low	10 percent losses

Fargo was the exception to this rule based on discussions with the city. For Fargo, the 1990 through 1994 average loss rate (17.5 percent) was used.

A discussion of demand projections is provided below on a city-by-city basis. The river operation simulation study relates the demand projections to the available flows in the rivers

a. City of Breckenridge

Breckenridge raw water demand in 1994 (a year with above normal precipitation) was 152,550,000 gallons, which is 114 gpc/d. A projected use of 580 acre-feet (188,994,000 gallons, which is 141 gpc/d) for residential, commercial, and public use was adopted for conditions in 2050. Both present and future uses for Breckenridge were assumed to rely on ground water.

b. City of Drayton

The city of Drayton has a major industrial water user, American Crystal Sugar. Currently, American Crystal Sugar's water right in the Drayton area is for 2,250 acre-feet per year or 733,165,000 gallons. The city expects a substantial component of industrial water could be used in the future. In 1994, the city used 60,385,000 gallons and had a population of 904, which is a use rate of 183 gpc/d. The use rate is high because of the large amount of industrial use and small population.

The projected use for Drayton (Tables 4 and 6) was provided by a letter dated February 9, 1995, from Drayton's consultant, Advanced Engineering and Environmental Services, Inc. (Steve Burian, personal communication).

These projections were based on estimates of use by American Crystal Sugar and a full-sized plant for Drayton Grain Processors. Estimates for other industries (Advanced Engineering, letter dated February 9, 1995) were discarded based on discussions with the city consultant due to the placement of a Cargill unit of industry near the city for modeling purposes.

c. City of East Grand Forks

The city of East Grand Forks (letter dated October 7, 1995, from Gary Hultburg, city of East Grand Forks, to Tom Sawatzke, Reclamation) reported 1994 raw water use at 548,293,000 gallons, which is 167 gpc/d (East Grand Forks, 1994). A future rate of 120 gpc/d is projected for residential, commercial, and public use. Industrial use is projected at 20 acre-feet for the year 2050. One of the major industries in East Grand Forks is the American Crystal Sugar Company. An increase in water use by this company was recently realized due to the addition of an ionization process. Past use was in the range of 214 acre-feet per year. Since the addition of the new process, annual use has nearly doubled based on 1994 data. Currently, the water right held by American Crystal Sugar in the East Grand Forks area amounts to 1,841 acre-feet per year. Full water right levels of use were included in the model to account for possible expansion of this company's water use in the future.

d. City of Fargo

The city of Fargo proved to be the most complex of the 10 Participant communities regarding forecasting future water use. This investigation undertook several examinations of Fargo’s water use to develop the best estimate of future demands. Early Reclamation estimates of population projections and city water demands were deemed too low, and the city's estimates appeared to be high. After several discussions with the city, Reclamation took into account the most recent Fargo raw water diversion data (1988 through 1996 – see Figure 3) to re-examine both population and water use rate projections for future conditions. Population figures were adjusted upward based on recent census information. A growth rate of 1.6 percent per year is now used in this analysis. The city of Fargo has recommended using 2 percent per year as the future growth rate.

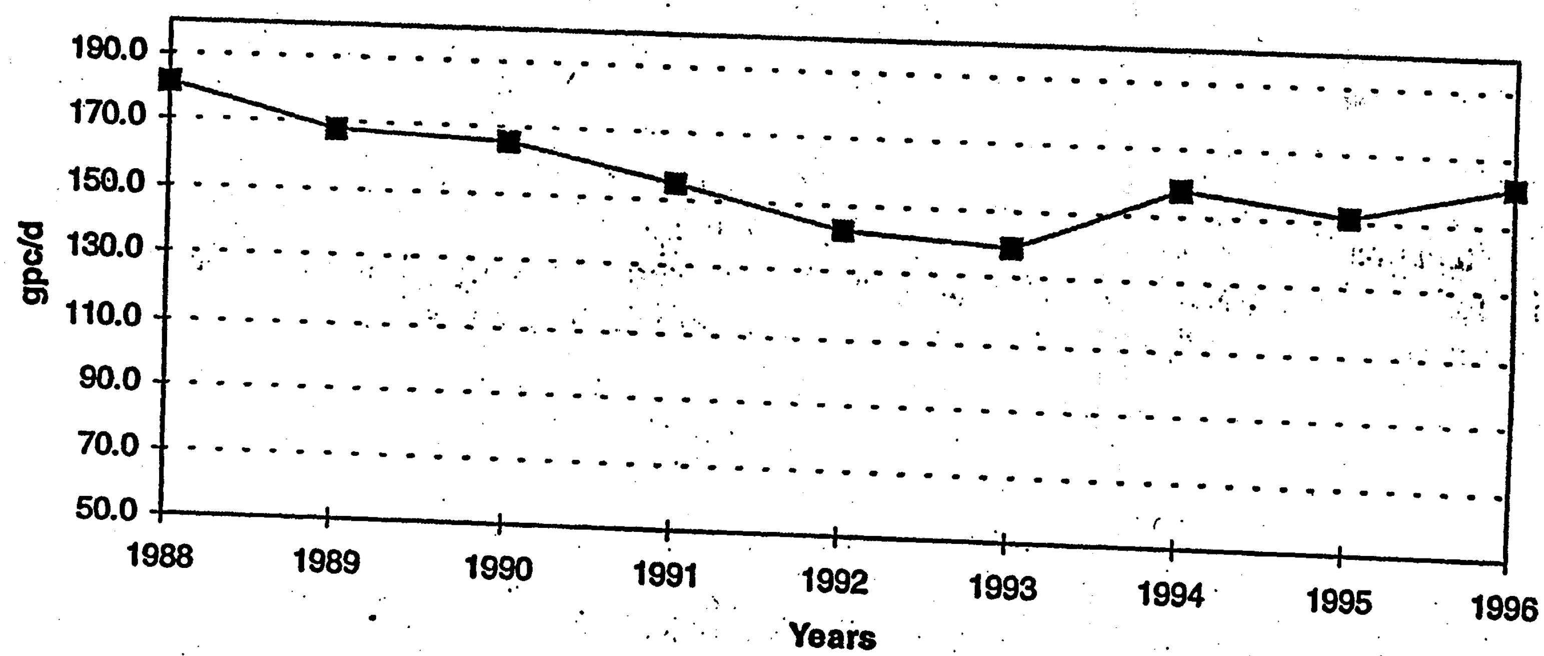

Figure 3: Fargo raw water diversion (per capita)

Reclamation modified its early water use projections based on the following information. The city of Fargo is concerned that the per capita use rate used for future projections by Reclamation is too low. The city projection (chart 1 of the December 23, 1994, letter to the State Engineer, Attachment A), which is based on a trend of linearly increasing per capita water use, appears to Reclamation to be a high estimate. The city has stressed the legitimacy of adopting the increasing use rate depicted in Attachment A, chart 1, for the purpose of their water demand projections. Their 2050 future raw water demand is based on a rate projection of 247 gpc/d. The 1988-1996 record of water use indicates a rate well below that forecast on chart 1. Therefore, the 1988-1996 data suggest that the city's forecasted water use rates may be too high. By contrast, a use rate of 120 gpc/d used as a regional estimate, without the benefit of detailed information, is likely too low.

The 1990 Fargo raw water demand (used in earlier drafts of the Reclamation Phase I, Part A report) resulted in a computed demand of 166 gpc/d. Additional information provided to Reclamation by the city (Attachment A, letter dated December 23, 1994, from Bruce D. Furness to David Sprynczynatyk) included city projections for future demand use. The information provided by this letter includes this M&I raw water demand of 166 gpc/d in 1990 and then projects increasing per capita demand to the year 2050. By contrast, as shown on Figure 3, the actual amount of raw water treated for 1991 through 1996 varied from 139 to 162 gpc/d. Therefore, the annual use figure does vary considerably and does not represent an immediately increasing trend.

Regarding the use variability, Chart 1 in Attachment A indicates a downward trend from 1988 to 1994, even though population was increasing. This trend is independent of climatic conditions during the period. Indeed, from 1987 through 1990, the annual precipitation in the area was well below the 20.77-inch annual average (1966-1994) of the National Weather Service records. From 1990 to 1994, the situation began to improve to near average and slightly above average precipitation levels. In addition to the climatic factors, the city of Fargo also experienced the largest number of water system breaks in 1988 (the highest use year). These factors indicate the flexibility in the Fargo water system. During drought periods, the city demonstrated the ability to conserve water. Also, had system breaks not occurred, or had the city distribution system been improved to limit breaks, raw water demands may have been even lower.

The most complete breakdown of the city's water use by sector was developed by the U.S. Army Corps of Engineers as part of its May 1985 Fargo Moorhead Urban Water Supply Study (Corps, 1985). The Water Supply Attachment (Volume 2) developed as a result of this study listed the following breakdown of Fargo's M&I water use at the time:

Residential	32 percent of total use
Commercial	35 percent of total use
Industrial	5 percent of total use
Public and Unaccounted for	28 percent of total use

Reclamation gathered additional information for the year 1994 (the most recent year with complete demand data available for the entire Red River Valley). This information (provided by Bob Welton - City Engineer, personal communication) was as follows:

1994 Raw Water Demand:	4,597,660,000 gallons
1994 Billed Water:	3,434,596,000 gallons

It should be noted that the commercial and industrial figure also contains an unspecified amount of residential use from apartment dwellers. Based on 1994 treated water records and the sector use percentages given above, the residential raw water demand would be 50.6 gpc/d. The combined commercial and industrial raw water demand would be 63.2 gpc/d.

In summary, Reclamation estimates of the city M&I use rate were modified based on this information, and the variability that has occurred in annual raw water demands is noted. Because 1988 was such an unusually high use year (drought and record number of water breaks), Reclamation's projections will use the 1990 use rate 166 gpc/d for the raw water demand. This per capita use rate will be extended to the year 2050 with no increasing use rate trend.

Reclamation's view is that public awareness and participation in water resource issues, and more specifically in water conservation efforts will have a subtle but important impact on future water needs. The result of these assumptions would be stabilization in water use rates that would be near today's existing use rates. Therefore, the capita use rate curve would flatten rather than increase.

The breakdown of the total use by sectors is assumed to remain in the same proportion shown in the Fargo-Moorhead Urban Water Supply Study (Corps, 1985). If new industry does come into the area and becomes a part of Fargo's water supply, Reclamation's per capita use estimate may need to be increased for industrial purposes. However, it is assumed that most new industrial developments would be located outside the city and would therefore not be on Fargo's distribution system. The 2050 Reclamation projection includes the development of a new Cargill type of industrial growth located near the city of Fargo, but this addition would have it's own separate water supply with a junior water right.

It should be noted that the basic assumptions of Fargo water use between the Phase I, Part A and Phase II portions of this study were basically the same. However, a misinterpretation of what would be considered a raw water demand from the river, and a delivery demand from the city resulted in too large a demand for Fargo being used in Phase I, Part A. For Phase II, the raw water demand was set at the 166 gpcpd rate rather than the delivery demand thus lowering the Reclamation demand for Fargo in the Phase II study. Part of this misinterpretation was due to a discrepancy of gauged intake versus outflow water from the city's water treatment plant. The Participant version of the city of Fargo demand remained the same in Phase II.

e. City of Grafton

A letter dated January 2, 1995, from Advanced Engineering and Environmental Services, Inc. provided current and projected use rates for Grafton. The city used 299,445,300 (city records) gallons in 1994 and had a population of 5,086, which was a use rate of 161 gpc/d. Industrial use is estimated to be 35 percent of the total, excluding unaccounted water.

The ethanol plant at Grafton (Alchem) obtains water from the city. They project an increase in water demand of 30 percent. In addition, Grafton projects substantial additional industrial development, another ethanol plant, and an agricultural processing plant, which would amount to an additional 35-percent increase in industrial water.

A future projection of industrial water use based on this information would result in approximately 432 acre-feet by the year 2050. A use rate of 120 gpc/d is projected for residential, commercial, and public use. Refer to water use projections discussed earlier in this chapter. Population for these future periods is projected to remain at present levels.

f. City of Grand Forks

Water use information provided by the city of Grand Forks shows a raw water demand in 1994 of 2,456,154,260 gallons. The population was 50,168, which indicates a use rate of 134 gpc/d. A projection of industrial water use in 2040 prepared by a consultant to the city of Grand Forks with city input was provided to Reclamation as attachments to a letter from Advanced Engineering and Environmental Services, Inc., dated December 16, 1994 (Advanced Engineering and Environmental Services, 1994). This projection is based on periodic additions of agricultural commodity processors, which typically have high water use. The city currently has several industrial water users of this type, with Simplot being the largest. Some of the other industrial users include Minnesota Dairy, Associated Potato Growers, Conte Luna Pasta Plant, and Red River Cement. The average growth rate projected is about 4 percent. The curve depicting future industrial water use was used to estimate the usage in year 2050 as 9,740 acre-feet.

g. City of Lisbon

Although not one of the participating focus communities, the city of Lisbon was considered in the modeling due to its mainstem location on the Sheyenne River. Modeling results for Lisbon were therefore discussed throughout this document. The city of Lisbon did not furnish present and future water usage figures so the full water right for the city was used in the model for present and future conditions. This use was not considered significant as compared to other cities due to smaller population and less industry. Based on the water right information provided by the state (see Attachment E) an annual demand of 373 acre-feet was used in the model.

h. City of Moorhead

In 1994, the city's total raw water use rate was 116 gpc/d. Approximately one-half of the supply has been derived from well water. In years such as 1994 when surface water quality was poor, the city relied heavily on well water. A new water treatment plant was put into operation in early 1995, thus giving the city more flexibility in its use of surface water. In 1996, it is expected that 85-90 percent of the water will come from the Red River. For the projection of future use, 120 gpc/d is assumed for residential, commercial, and public use. Refer to water use projections discussed earlier in this chapter. The city also has industrial users. A projection of future use for industry was roughly estimated at 1,060 acre-feet for 2025 and 1,150 acre-feet for 2050.

i. City of Valley City

The 1994 use rate for Valley City was 112 gpc/d (Donald Olafson, Valley City Water Treatment Plant, personal communication). A total raw water projected future use rate of 149 gpc/d was used, including an industrial water use of 357 acre-feet for the year 2050, for a total projection of 154 gpc/d.

j. City of Wahpeton

Wahpeton raw water demand in 1994 amounted to 389,256,000 gallons, which equates to 116 gpc/d. A projected use of 1,410 acre-feet (459,450,000 gallons) for residential, commercial, and public use was estimated for future 2050 conditions. Both present and future uses for Wahpeton were assumed to rely on ground water.

k. City of West Fargo

The water use billed to customers by West Fargo in 1994 was 454,865,000 gallons. This is considered to be less than a normal use amount since 1994 was a year with above normal precipitation. Based on use rates of similar cities, a rate of 120 gpc/d for residential, commercial, and public use was adopted for future use projections. Industrial use was estimated at 657 acre-feet for the year 2050.

Water for the city in 1994 was primarily supplied from ground water. Under future (year 2050) conditions, this ground water use was kept constant. However, any increase in demand since 1994 was, for modeling purposes, assumed to receive its supply from surface water. Therefore, under Reclamation and participant demand scenarios in the year 2050, all but the 1994 level of demand was supplied by surface water.

l. Cities Not Directly Included in the River Operations Model

Cities that get their M&I supply from surface water but were not included individually in the river operation studies in detail include Langdon, Neche, Mayville, Park River, Pembina, and Walhalla. Rather, the demands from these cities were included in the tributary depletions from the USGS study. Any demands on the main stem from cities, such as Pembina, were included based on water rights or the estimated demand portion of the city's water right. In general, streamflow records available during the 1930s show many months of no flow or very low flows. During a drought period similar to the 1930s, these cities would have difficulty supplying their water needs. Other periods of drought included in the simulation period of record could also prove difficult for some of these municipalities. Demands for each of these cities are discussed below.

Langdon: The city of Langdon had a population of about 2,085 in 1994 and gets its water from Mount Carmel Dam and Langdon City Pond. Insufficient information was obtained to comment on their water supply during drought periods. Raw water for the city of Langdon is supplied to the city treatment plant from two reservoirs: the Mount Carmel Dam and Mulberry Reservoir. Mount Carmel Dam is located 13 miles north of the city of Langdon, while Mulberry Reservoir is located immediately south of the city water treatment plant. Seasonal water quality parameters are used to delegate which raw water source is used to ensure that the best possible water source is used for treatment (Advanced Engineering, 1995).

The use of water by the city totals 81,300,000 gallons per year from Mount Carmel Dam and 53,600,000 from Mulberry Creek Reservoir. The city sells water to Langdon Rural Water Users, Inc. A proposed expansion of the Langdon water system will likely increase the total usage by 21,000,000 gallons per year. In 1994, the city's portion of the total demand (raw water) was 80,878,447 gallons. This information was not included in the HYDROSS model in detail; rather the depleted outflow based on earlier U.S. Geological Survey studies by Guenther (Guenther, et. Al., 1991) was used. It is recommended that if more detailed studies are warranted in the future, this information should be included

Mayville: The city of Mayville had a population of about 2,025 in 1994 and obtains water from the Goose River. The minimum annual flow of 2,515 acre-feet occurred in 1937. This low flow condition was almost repeated in 1977 with an annual flow of 2,517 acre-feet. The rate of water use (raw water) for the city of Mayville in 1994 was estimated to be 70,946,000 total gallons. Currently, projected growth for this city is considered stable. However, potential growth in the residential and commercial areas could occur. Future studies should investigate this possibility in more detail. One potential source of growth could be additional agricultural processing plants (city of Mayville, personal communication, 1995).

It should be pointed out that concerns exist regarding available water from the Goose River to the city of Mayville during extreme drought. If detailed studies are done, more information on tributary flows should be included in the HYDROSS modeling.

Neche: The city of Neche had a population of 427 in 1994. The future population of Neche is expected to remain stable at about 450. The city of Neche sells treated water to the Manitoba Water Board, about 130 million gallons annually, and to the North Valley Water Association, about 2 million gallons annually. They estimate that 5,460 people are served from their system, and the total annual use is 160 million gallons or about 490 acre-feet per year. The source of water is the Pembina River. The critical drought period of the 1930s had many months of zero flow, and the lowest water year on record was in 1939. During a drought period similar to the 1930s, Neche would have difficulty supplying its water needs.

Park River: The city of Park River is on the Park River upstream from Grafton and below Homme Dam and Reservoir from which it obtains its water. The city had a population of 1,532 in 1994, and their current annual water use is 64,522,000 gallons. Streamflow records are available on the Park River at Grafton as previously mentioned. Homme Dam was constructed in 1950 after the 1930s critical period. The records for Park River indicate many months of zero flow. Without storage, the city would not be able to meet its needs in a critical drought period. An operation study of Homme Dam could be made to determine if they have adequate storage to meet demands during critical drought periods. One important component of such a study should be the reduction in reservoir capacity due to sediment inflow. Due to this sedimentation, the city has been prompted to raise its water line inlet to maintain water quality. Although Park River does now have an adequate water supply, quality problems could limit this supply in the future. One other potential issue for Park River is that the Homme Dam is currently under investigation under the Dam Safety Assurance Program. Potential outcomes of this investigation include expanding or replacing the existing spillway or removing the dam. If the dam removal became a reality, an alternate source of water would have to be found. It should be noted that any adverse action to the dam and reservoir could also potentially affect the city of Grafton, which was one of the local contributing sponsors of the construction of the dam. These potential changes to the supply of Park River and Grafton were not within the scope of this study. However, it is important to note these possibilities if more detailed studies are warranted. The HYDROSS model is considered a good computational vehicle for these alternative scenarios.

Pembina: The city of Pembina obtains water from the Red River. Pembina's population was 621 in 1994. Because it is downstream of Drayton, which had minor water shortages in the river operation study critical period and because it is below the mouth of the Pembina River, it would appear by inspection that Pembina would have an adequate water supply to meet its needs nearly every year.

Walhalla: The city of Walhalla, located upstream of Neche on the Pembina River, uses ground water but could potentially have problems due to water quality. If they have a need to use surface water, the recorded flows of the Pembina River (as previously discussed) show there could be difficulties during critical drought periods. Walhalla had a population of 1,052 in 1994.

m. Cargill Corn Processing Plant and Future Industry Centers

The existing Cargill (formerly ProGold Corn) milling plant near Wahpeton has been issued a surface water permit for 6,000 acre-feet per year from the Red River. The initial size of the plant is for 80,000 bushels per day (bu/day), with an initial water consumption of about 1,410 acre-feet per year. Future plans include a second phase that would increase the plant's output to 160,000 bu/day, which would consume approximately 3,000 acre-feet of water per year. A final phase could increase capacity to 320,000 bu/day, with a water consumption rate of 5,640 acre-feet per year. If the water recycling system works as expected, 6,000 acre-feet would be sufficient at the ultimate plant development of 320,000 bu/day.

It should be noted that a second permit to use 3,000 acre-feet per year from the Wahpeton Buried Valley aquifer has been issued. This permit is intended as a reserve source of water. This ground water resource has been included in the hydrologic model based on Cargill's water permit issued from the NDSWC. The local aquifer does have a limited withdrawal rate over the 54-year simulation period to prevent mining of the aquifer. This limitation is illustrated in Table 8 Since the model did not have the capability to decide exactly when to turn on the ground water pumps as a result of low flow in the river, the model allowed the plant to take available water from the river and then utilize the ground water resource to apply to shortages.

The combined diversion for the plant will not exceed 6,000 acre-feet per year. The 6,000 acre-feet demand was used in all model simulations. Returns of nonconsumed water from the plant were passed back to the river the following month after use. The monthly demand distribution for plant use was assumed to be evenly distributed throughout the year. The overall efficiency of the plant operation was set at 50 percent. Because the Cargill water permit is new, a corresponding priority date was placed on the Cargill water right in the HYDROSS model. Thus, Cargill is considered to have a junior right on the river and will be one of the first entities denied surface water during a dry period.

In other areas of the basin, it is suggested that more Cargill-type plants (or other large industrial plants) may eventually be developed. After an analysis of potential industrial use, it was decided to locate four additional Cargill-type plants to represent additional industrial development. These plants were designated New Industry 2, 3, 4, and 5 for modeling purposes. They were input to the model with similar demand and efficiency parameters as the existing Cargill plant (with the exception of utilizing a ground water supply). The distribution of these units in the Red River Valley was as follows:

New Industry2	Red River near Fargo
New Industry3	Red River near Abercrombie
New Industry4	Red River near Drayton
New Industry5	Sheyenne River near Kindred

These plants add an additional 24,000 acre-feet of demand to the valley. Each new plant was given a low priority (future) date and were the first to experience shortages in the study area. Under the conservation scenario discussed later in this report, each plant has a total demand of 5,100 acre-feet or a total of 20,400 acre-feet per year.

n. Rural Water Systems

Rural water systems were generally not included in the hydrologic model simulations since all but 1 of the 12 are ground water users. However, these demands were included in scenarios that showed the full M&I demand could be met to determine the incremental cost of meeting M&I and rural demands combined.

There is an overall concern by managers of the rural water systems, that growth and expansion of their facilities will someday require additional water supplies. The growth in the use of rural water systems has been noted by all of the existing systems, and the existing water use rates are presented in section "2.5.2 Rural Water Supply" of the Phase I, Part A report. This trend to increase the size of the rural water system is based upon the desire of the rural and small community populations to connect with the rural water providers in order to have a better quality water supply and, in some cases, a more reliable water supply. This trend of increasing numbers of users does not fit with the population projections of stable or declining trends in the rural and small community sectors. There is, however, a real trend in increasing service connections and is a matter of individuals and small communities changing their point of use from individual well supplies or small community well supplies to the rural water system supplier.

Table 8 displays individual rural water system needs for the year 2050.

Table 8: Estimated Reclamation 2050 Projected Rural Water System Demands/Shortages

Agassiz Water Users, Inc.

Table of Future Demands and Shortages Using 120 GPCD Use Rate

Ac-Ft Permit: 800	Monthly %	Acre-Ft 2050 Low Use Est.	Acre-Ft 2050Low Shortage	GPM 2050Low Shortage	Acre-Ft 2050 High Use Est.	Acre-Ft 2050 High Shortage	GPM 2050High Shortage
January	0.088	70	0	-2	75	-4	-33
February	0.079	64	0	-2	68	-4	-33
March	0.088	71	0	-2	75	-5	-33
April	0.072	58	0	-2	62	-4	-28
May	0.089	71	0	-2	75	-5	-33
June	0.101	81	0	-2	85.6	-5.2	-39
July	0.099	79	0	-2	84	-5	-37
August	0.088	70	0	-2	75	-4	-33
September	0.072	58	0	-2	61	-4	-28
October	0.086	69	0	-2	73	-4	-32
November	0.067	54	0	-1	57	-3	-26
December	0.072	58	0	-2	62	-4	-27
Total	1.000	803	-3		851	-51	

Proposed future diversion combined with Walsh and Tri County. Pumping from Red River just below confluence with Park River, pipeline to Dahlen with branch to Johnston.
Aquifer used is the Inkster.

Cass Rural Water Users, Inc. (using full 1825 ac-ft appropriation)

Table of Future Demands and Shortages Using 120 GPCD Use Rate

Ac-Ft Permit: 1825	Monthly %	Acre-Ft 2050 Low Use Est.	Acre-Ft 2050Low Shortage	GPM 2050Low Shortage	Acre-Ft 2050 High Use Est.	Acre-Ft 2050 High Shortage	GPM 2050High Shortage
January	0.076	265	-126	-923	334	-196	-1428
February	0.073	254	-121	-979	320	-187	-1514
March	0.077	267	-127	-931	337	-197	-1440
April	0.081	282	-135	-1015	356	-208	-1570
May	0.089	309	-147	-1075	389	-228	-1663
June	0.100	349	-166	-1255	440	-257	-1942
July	0.098	343	-163	-1192	432	-253	-1845
August	0.094	327	-156	-1136	412	-241	-1758
September	0.082	285	-136	-1026	360	-210	-1586
October	0.079	274	-131	-954	346	-202	-1477
November	0.075	261	-124	-938	329	-192	-1452
December	0.078	272	-129	-945	342	-200	-1462
Total	1.000	3488	-1663		4397	-2572	

Proposed diversion on the Sheyenne River about one half mile downstream of Horace.
Proposed pumping plant and pipeline from the river diversion to Casselton
Aquifer used is the West Fargo South and Sheyenne Delta.

Grand Forks-Traill Water Users, Inc.

Table of Future Demands and Shortages Using 140 GPCD Use Rate

Ac-Ft Permit: 1712	Monthly %	Acre-Ft 2050 Low Use Est.	Acre-Ft 2050Low Shortage	GPM 2050Low Shortage	Acre-Ft 2050 High Use Est.	Acre-Ft 2050 High Shortage	GPM 2050High Shortage
January	0.088	246	-96	-699	374	-224	-1632
February	0.079	223	-87	-701	338	-202	-1636
March	0.088	247	-96	-701	375	-224	-1637
April	0.072	203	-79	-596	308	-185	-1392
May	0.089	248	-97	-706	378	-226	-1649
June	0.101	282	-110	-829	429	-257	-1935
July	0.099	277	-108	-788	421	-252	-1840
August	0.088	246	-96	-700	374	-224	-1633
September	0.072	202	-79	-593	307	-183	-1384
October	0.086	241	-94	-687	367	-220	-1603
November	0.067	187	-73	-550	285	-170	-1284
December	0.072	203	-79	-577	309	-185	-1348
Total	1.000	2805	-1093		4263	-2551	

Proposed diversion on Red River just upstream from the city of Grand Forks.
Pumping plant with pipeline to Thompson
Aqufier used is the Elk Valley.

Barnes Rural WaterUsers, Inc.

Table of Future Demands and Shortages Using130 GPCD Use Rate

Ac-Ft Permit: 1100	Monthly %	Acre-Ft 2050 Low Use Est.	Acre-Ft 2050Low Shortage	GPM 2050Low Shortage	Acre-Ft 2050 High Use Est.	Acre-Ft 2050 High Shortage	GPM 2050High Shortage
January	0.076	65	19	0	70	14	0
February	0.073	62	18	0	67	13	0
March	0.077	65	19	0	70	14	0
April	0.081	69	20	0	74	15	0
May	0.089	75	22	0	81	16	0
June	0.100	85	25	0	92	18	0
July	0.098	83	25	0	90	18	0
August	0.094	79	24	0	86	17	0
September	0.082	69	21	0	75	15	0
October	0.079	67	20	0	72	14	0
November	0.075	63	19	0	69	14	0
December	0.078	66	20	0	72	14	0
Total	1.000	849	251		919	181	

Aquifer used is the Spiritwood.

Dakota Water Users, Inc.

Table of Future Demands and Shortages Using 120 GPCD Use Rate

Ac-Ft Permit: 575	Monthly %	Acre-Ft 2050 Low Use Est.	Acre-Ft 2050Low Shortage	GPM 2050Low Shortage	Acre-Ft 2050 High Use Est.	Acre-Ft 2050 High Shortage	GPM 2050High Shortage
January	0.076	91	-47	-345	110	-67	-486
February	0.073	87	-45	-366	106	-64	-515
March	0.077	92	-48	-348	111	-67	-490
April	0.081	97	-50	-380	117	-71	-534
May	0.089	106	-55	-402	128	-78	-566
June	0.100	120	-62	-470	145	-88	-661
July	0.098	118	-61	-446	142	-86	-628
August	0.094	112	-58	-425	136	-82	-598
September	0.082	98	-51	-384	119	-72	-540
October	0.079	94	-49	-357	114	-69	-502
November	0.075	90	-47	-351	108	-65	-494
December	0.078	93	-48	-354	113	-68	-497
Total	1.000	1197	-622		1450	-875	

Proposed pumping plant in Lake Ashtabula, at approx. Hwy 26 crossing.
Pipeline from pumping plant to Finley.
Aquifers used are the Spiritwood and the McVille

Langdon Rural Water Users, Inc.

Table of Future Demands and Shortages Using 100 GPCD Use Rate

Ac-Ft Permit: 481	Monthly %	Acre-Ft 2050 Low Use Est.	Acre-Ft 2050Low Shortage	GPM 2050Low Shortage	Acre-Ft 2050 High Use Est.	Acre-Ft 2050 High Shortage	GPM 2050High Shortage
January	0.088	61	-19	-137	70	-28	-205
February	0.079	55	-17	-137	64	-25	-205
March	0.088	61	-19	-137	70	-28	-205
April	0.072	50	-15	-117	58	-23	-175
May	0.089	62	-19	-138	71	-28	-207
June	0.101	70	-22	-162	81	-32	-243
July	0.099	69	-21	-154	79	-32	-231
August	0.088	61	-19	-137	70	-28	-205
September	0.072	50	-15	-116	58	-23	-174
October	0.086	60	-18	-135	69	-28	-201
November	0.067	46	-14	-108	53	-21	-161
December	0.072	50	-15	-113	58	-23	-169
Total	1.000	695	-214		801	-320	

Proposed diversion from the Red River near Hwy 81. Diversion will be for Langdon Rural
Pipeline will extend to Cavalier and on to Langdon @ 245 gpm

Table 8 (Continued): Estimated Reclamation 2050 Projected Rural Water System Demands/Shortages

North Valley Water Association, Inc.

Table of Future Demands and Shortages Using 120 GPCD Use Rate

Ac-Ft Permit:		Acre-Ft	Acre-Ft	GPM	Acre-Ft	Acre-Ft	GPM
1430		2050 Low	2050Low	2050Low	2050 High	2050 High	2050High
	Monthly %	Use Est.	Shortage	Surplus	Use Est.	Shortage	Surplus
January	0.088	92	33	0	116	9	0
February	0.079	83	30	0	105	8	0
March	0.088	92	33	0	117	9	0
April	0.072	76	27	0	96	7	0
May	0.089	93	34	0	118	9	0
June	0.101	106	38	0	134	10	0
July	0.099	104	38	0	131	10	0
August	0.088	92	33	0	117	9	0
September	0.072	76	27	0	96	7	0
October	0.086	90	33	0	114	9	0
November	0.067	70	25	0	89	7	0
December	0.072	76	27	0	96	7	0
Total	1.000	1050	380		1329	101	

Proposed diversion from the Red River near Hwy 81 for Langdon Rural Water only
North Valley Water Users do not exhibit shortage. Langdon pipeline will extend to Cavalier and on to La
Aquifer used is the Icelandic

Traill County Rural Water Users, Inc.

Table of Future Demands and Shortages Using 120 GPCD Use Rate

Ac-Ft Permit:		Acre-Ft	Acre-Ft	GPM	Acre-Ft	Acre-Ft	GPM
644		2050 Low	2050Low	2050Low	2050 High	2050 High	2050High
	Monthly %	Use Est.	Shortage	Shortage	Use Est.	Shortage	Shortage
January	0.076	54	-5	-35	54	-5	-35
February	0.073	52	-5	-37	52	-5	-37
March	0.077	54	-5	-35	54	-5	-35
April	0.081	57	-5	-38	57	-5	-38
May	0.089	63	-6	-41	63	-6	-41
June	0.100	71	-6	-48	71	-6	-48
July	0.098	69	-6	-45	69	-6	-45
August	0.094	66	-6	-43	66	-6	-43
September	0.082	58	-5	-39	58	-5	-39
October	0.079	56	-5	-36	56	-5	-36
November	0.075	53	-5	-36	53	-5	-36
December	0.078	55	-5	-36	55	-5	-36
Total	1.000	707	-63		707	-63	

Shortage for Traill Co. Water users could be met by pumping plant at the Red River near Halstad, Mn
Shortage for Traill Co. Water users could be met by small increase in groundwater pumping
Aquifer used is the Galesburg

Walsh WaterUsers, Inc.

Table of Future Demands and Shortages Using 130 GPCD Use Rate

Ac-Ft Permit:		Acre-Ft	Acre-Ft	GPM	Acre-Ft	Acre-Ft	GPM
804		2050 Low	2050Low	2050Low	2050 High	2050 High	2050High
	Monthly %	Use Est.	Shortage	Shortage	Use Est.	Shortage	Shortage
January	0.088	75	-4	-31	88	-17	-127
February	0.079	68	-4	-31	80	-16	-128
March	0.088	75	-4	-31	88	-18	-128
April	0.072	62	-4	-27	73	-14	-109
May	0.089	75	-4	-31	89	-18	-129
June	0.101	86	-5	-37	101	-20	-151
July	0.099	84	-5	-35	99	-20	-144
August	0.088	75	-4	-31	88	-17	-128
September	0.072	61	-3	-26	72	-14	-108
October	0.086	73	-4	-31	86	-17	-125
November	0.067	57	-3	-24	67	-13	-100
December	0.072	62	-4	-26	73	-14	-105
Total	1.000	853	-49		1003	-199	

Proposed future diversion combined with Agassiz and Tri County. Pumping (650gpm) from Red River
just below confluence with Park River, pipeline to Dahlen with branch to Johnston.
Aquifer used is the Fordville

Southeast Water Users, Inc.

Table of Future Demands and Shortages Using 100 GPCD Use Rate

Ac-Ft Permit:		Acre-Ft	Acre-Ft	GPM	Acre-Ft	Acre-Ft	GPM
600		2050 Low	2050Low	2050Low	2050 High	2050 High	2050High
	Monthly %	Use Est.	Shortage	Shortage	Use Est.	Shortage	Shortage
January	0.076	84	-38	-277	110	-65	-473
February	0.073	80	-36	-294	106	-62	-502
March	0.077	84	-38	-280	111	-65	-477
April	0.081	89	-40	-305	118	-69	-520
May	0.089	97	-44	-323	129	-76	-551
June	0.100	110	-50	-377	145	-85	-643
July	0.098	108	-49	-358	143	-84	-611
August	0.094	103	-47	-342	136	-80	-583
September	0.082	90	-41	-308	119	-70	-526
October	0.079	86	-39	-287	114	-67	-489
November	0.075	82	-37	-282	109	-64	-481
December	0.078	86	-39	-284	113	-66	-484
Total	1.000	1100	-500		1452	-852	

Proposed diversion from the Sheyenne River just downstream from Lisbon.
Pumping from Sheyenne River to Wyndmere
Aquifer used is the Hankinson

Tri-County Water Users, Inc.

Table of Future Demands and Shortages Using 120 GPCD Use Rate

Ac-Ft Permit:		Acre-Ft	Acre-Ft	GPM	Acre-Ft	Acre-Ft	GPM
392		2050 Low	2050Low	2050Low	2050 High	2050 High	2050High
	Monthly %	Use Est.	Shortage	Shortage	Use Est.	Shortage	Shortage
January	0.088	69	-35	-254	75	-41	-299
February	0.079	63	-31	-254	68	-37	-300
March	0.088	69	-35	-255	76	-41	-300
April	0.072	57	-29	-217	62	-34	-255
May	0.089	70	-35	-257	76	-41	-303
June	0.101	79	-40	-301	86	-47	-355
July	0.099	78	-39	-286	85	-46	-338
August	0.088	69	-35	-254	75	-41	-300
September	0.072	57	-29	-215	62	-34	-254
October	0.086	68	-34	-249	74	-40	-294
November	0.067	53	-26	-200	57	-31	-236
December	0.072	57	-29	-210	62	-34	-247
Total	1.000	789	-397		860	-468	

Proposed future diversion combined with Walsh and Agassiz. Pumping from Red River
just below confluence with Park River, pipeline to Dahlen with branch to Johnston.
Aquifer used is the Elk Valley

Ransom-Sargent Water Users, Inc.

Table of Future Demands and Shortages Using 100 GPCD Use Rate

Ac-Ft Permit:		Acre-Ft	Acre-Ft	GPM	Acre-Ft	Acre-Ft	GPM
550		2050 Low	2050 Low	2050Low	2050 High	2050 High	2050High
	Monthly %	Demand	Shortage	Demand	Demand	Shortage	Demand
January	0.076	61	-19	-139	65	-23	-166
February	0.073	58	-18	-148	62	-22	-176
March	0.077	61	-19	-141	65	-23	-167
April	0.081	65	-20	-153	69	-24	-183
May	0.089	71	-22	-163	75	-26	-193
June	0.100	80	-25	-190	85	-30	-226
July	0.098	79	-25	-180	83	-29	-214
August	0.094	75	-24	-172	79	-28	-204
September	0.082	66	-21	-155	69	-24	-184
October	0.079	63	-20	-144	67	-24	-172
November	0.075	60	-19	-142	64	-22	-169
December	0.078	62	-20	-143	66	-23	-170
Total	1.000	801	-251		849	-299	

Aquifer proposed for use is the Sheyenne Delta

2. Monthly Demand Distribution

The demands on a municipal water supply are not constant from day to day or month to month. This appraisal-level estimate of water demand will use a monthly demand distribution to reflect the seasonal variation of the water supply needs. The monthly demand distribution for Grand Forks was based on actual use for the year 1994 and is as listed in Table 9 below. The same distribution is used for East Grand Forks.

Table 9: Grand Forks Monthly Demand Distribution

Month	Percent of Annual Demand
January	7.5
February	7.4
March	7.6
April	7.6
May	8.8
June	9.1
July	8.2
August	10.1
September	8.9
October	8.8
November	7.9
December	8.1

The monthly distribution for Fargo is also used for Moorhead, West Fargo, Grafton, Drayton, and Valley City. The percentage distribution is as follows in Table 10:

Table 10: Fargo Monthly Demand Distribution

Month	Percent of Annual Demand
January	7.1
February	7.8
March	8.4
April	8.3
May	9.4
June	10.5
July	9.1
August	8.5
September	8.2
October	7.8
November	7.4
December	7.5

3. Return Flows

The following section discusses assumptions made regarding return flows from M&I and other uses. Return flow estimation is usually one of the more difficult areas to assess in hydrologic modeling. In many cases, little or no data exists and assumptions must be derived from regional estimates or studies conducted in the general vicinity of the study area.

a. Return Flows from M&I Use

A value of 85 percent of the demand is assumed for return flow from onsite M&I water use during the November-April period and 65 percent during the May-October period. Some variables included in the depletion of M&I water include the amount of lawn watering, age of a system (which influences how much it leaks), soil type (deep percolation from lawn and park irrigation and system leaks vary according to the soil type), and climate.

In addition, losses from the raw water intake point to the wastewater were included for each city. Data for those losses were available for 1994 and modified for future conditions based on whether each city fit into a low, medium, or high loss category. The reader is referred to section "Water Use Projections section in this chapter" for more detail.

It should be noted that a major change from the Phase I, Part A to the Phase II hydrologic modeling proved to change M&I shortages significantly. The Phase I, Part A model versions allowed return flows for multiple cities in the same node to return flows to the same node of diversion. This was to simulate the close proximity of diversions to return flows from a city's operation. In this case the individual node water balances were correct and a level of shortages was computed for the Phase I, Part A report. However, as more experience with the model was gained and more detailed analysis of the results was undertaken early in Phase II, it was speculated that the shortages derived in the Phase I, Part A effort may be actually low. Upon further investigation and testing of the model, it was discovered that the return flows did not actually return to the bottom of the node, but rather returned to the river upstream of the next diversion point. Therefore, in the case of Fargo-Moorhead and Grand Forks-East Grand Forks, the downstream city was benefitting unrealistically from the return flows of the city just upstream. After several sensitivity runs, it was decided to reposition these city return flows to the next downstream node, regardless of distance to that node to eliminate this problem. The result was an increase in computed shortages for several cities. This increase however was determined to more accurately represent the operations on the river. If a more detailed study were to be undertaken in the future, it is recommended that the affected nodes be broken down into sub-nodes with more detail as to the diversion/return flow situation in congested diversion areas.

b. Return Flows from Other Uses

Several assumptions regarding other uses in the study area were required to more accurately depict the full return flow component of the hydrologic systems of the Sheyenne and Red Rivers. As part of this return flow estimation, assumptions regarding conveyance and onsite water use efficiencies were required. Further, assumptions regarding deep percolation (lost to the system) and returnable flows to the river had to be made for each use.

Regarding irrigation, since most acreage is under sprinkler irrigation, a conveyance efficiency of 90 percent was used. Onsite efficiency was based on a combination of crop patterns, acreage under cultivation, and prevailing climatological conditions. The monthly pattern for a diversion's returns was assumed to be 86.68 percent the month of the diversion, 12 percent the month after the diversion, and 1.32 percent the following month. These values were derived from a similar study in Montana and could be refined, as more information becomes available. Other uses, such as golf course watering, had similar efficiencies. It should be noted that return flows from irrigation uses were essentially zeroed in the HYDROSS model (based on information provided by the North Dakota State University extension service). Little excess water from irrigation exists due to the high efficiency of use and most, if not all, of the excess irrigation water is lost to evaporation or deep percolation.

Regarding some miscellaneous uses, such as fish, wildlife, and recreation, no data was available regarding actual use or computation of return flows. Several of these uses were based on water rights in the model. For these uses, conveyance efficiencies were set at 60 percent, and onsite efficiencies were set at 80 percent. Return flows were assumed to return to the river the month of use. Since the amount of use by these miscellaneous water rights was small in the overall system, refinements were not deemed necessary for this level of study.

4. River and Reservoir Operations

The following sections discuss modeling procedures and assumptions used in regard to the Red and Sheyenne River operations, including the operations of existing reservoirs in the basin.

a. Lakes Orwell and Traverse and Upper Red River Operations

Detail regarding the operation of Lake Orwell on the Otter Tail River in Minnesota and Lake Traverse on the upper Red River (Bois de Sioux River) between South Dakota and Minnesota are not fully developed due to the use of the USGS natural and depleted flows in this study. Instead of detailed operations of the reservoir, only depleted outflows resulting from operations were used as inflow in the upper reaches of the Red River. The depleted flow entering the Red River from these reservoir systems are assumed to account for operational releases, spills, evaporation, and flood control. It is also assumed that any net changes in the water budgets of these reservoirs water are insignificant.

Regarding operations of the upper Red River, the diversion point for Moorhead was assumed to be upstream of Fargo's diversion point, with the municipal and industrial (M&I) return flows returning to the stream below Fargo's diversion. Fargo's first source of M&I water is assumed to be the Red River, with the unmet demand becoming the demand on the Sheyenne River. In terms of priority, Fargo's water right on the Red River is senior to Grand Forks. More detail regarding the demand assumptions of each of these cities are found in the Water Use Projections section presented earlier in this document.

b. Lake Ashtabula Operations

For modeling purposes, monthly inflows to Lake Ashtabula (Bald Hill Dam) were estimated using the 1991 and 1993 USGS studies by Guenther et al. These flows were considered to be natural condition flows depleted by upstream diversions or regulation that are computed by the model.

The monthly net evaporation loss at Lake Ashtabula was estimated by using monthly evaporation and precipitation data at the reservoir using local climatological stations. Computation of monthly net evaporation was done using the computed net evaporation rate and the reservoir surface area based on the capacity at the end of the previous month. The surface area at the end of each month was estimated using an equation of area as a function of capacity and was derived from an elevation area capacity table obtained from the Corps of Engineers. The free water surface evaporation minus the normal monthly precipitation provided an estimated average net evaporation rate for Lake Ashtabula of 22.31 inches annually.

The HYDROSS program computed the end-of-month reservoir content as the sum of the inflow, less bypasses, M&I releases, and evaporation. For the year 2050 condition, Lake Ashtabula contents were limited to 66,600 acre-feet during the months of March through September. The original capacity of 70,700 acre-feet at the top of conservation pool has been reduced to 66,600 acre-feet by the estimated amount of sediment deposition in the year 2050. To accommodate spring flood control, reservoir releases were simulated, starting in October, to lower the reservoir content to 46,900 acre-feet by the first of March. The original area-capacity curve for Lake Ashtabula is illustrated in Figure 4.

Releases were made on a straight-line basis to accommodate the monthly decrease in reservoir content. For the months of October through February, the reservoir content was allowed to be drawn down for flood control purposes. Although the minimum conservation pool is stated to be 1,200 acre-feet, a minimum capacity of 28,000 acre-feet (elevation 1257 feet) was selected as a point to stop withdrawals (Corps, 1983, rev.). At elevation 1257 feet, the reservoir still has a surface area of about 1,500 acres. Maintaining a minimum pool would be important for recreation and fish and wildlife (Corps, 1983, rev.). The surface area drops off very rapidly below this level. No formal drought operation plan is available for Lake Ashtabula. Rather, during dry periods, the users and the State can modify operations in cooperation with the Corps on an as-needed basis. Table 11 and Figure 5 list pertinent design data for Lake Ashtabula.

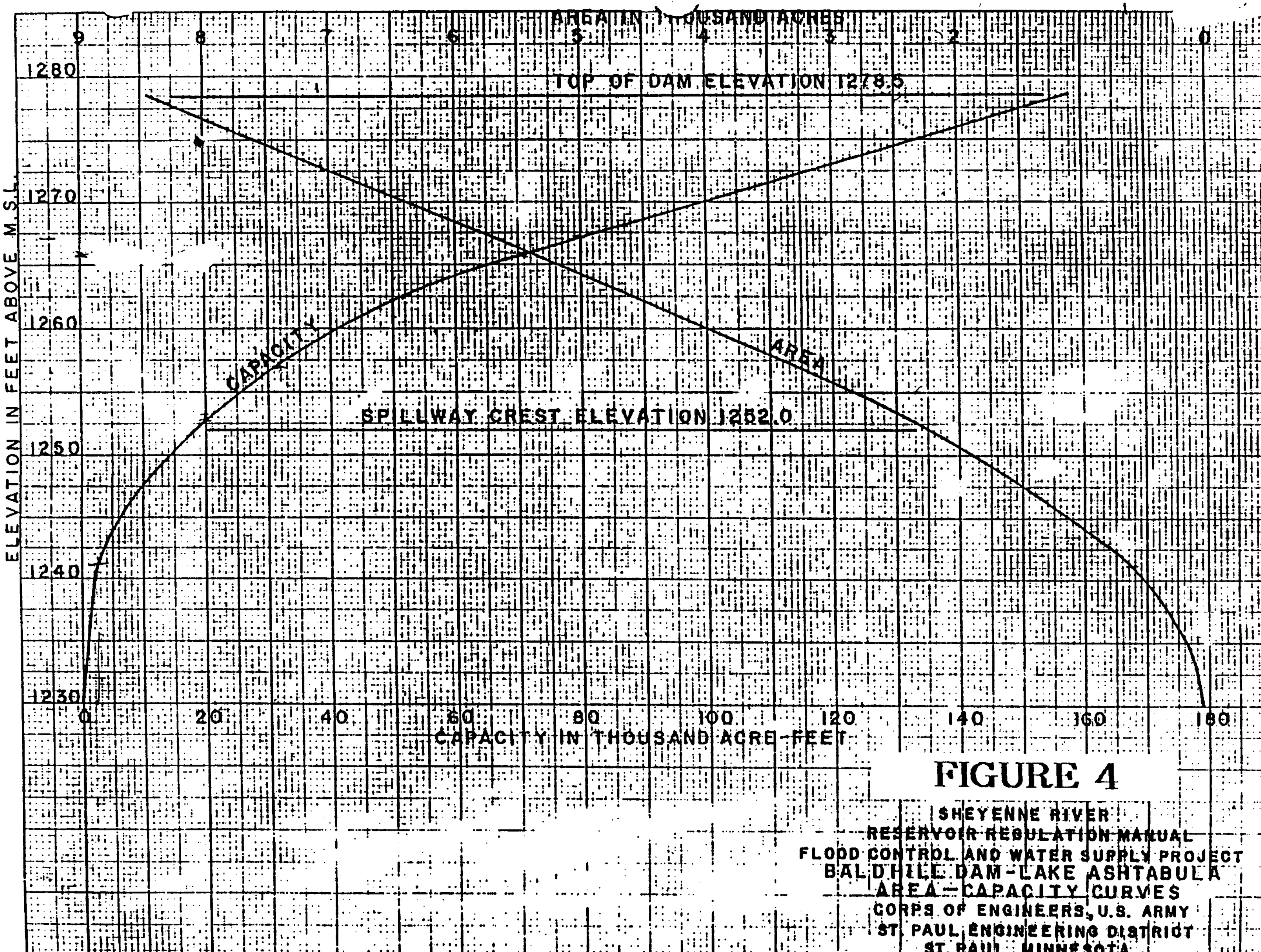

FIGURE 4

SHEYENNE RIVER
RESERVOIR REGULATION MANUAL
FLOOD CONTROL AND WATER SUPPLY PROJECT
BALDHILL DAM-LAKE ASHTABULA
AREA-CAPACITY CURVES
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

Table 11: Lake Ashtabula Pertinent Design Data (Existing Conditions)

Description	Elevation	Content (acre-feet)	Area (Acres)
Dam Height	61.0	-	-
Top of Dam Elevation	1278.5	158,000*	8,400*
Top of Flood Pool (feet)	1273.2	120,000*	7,150*
Top of Overflow Spillway Crest	1271.0	105,000*	6,600*
Top of Gates (proposed)	1271.0	105,000*	6,600*
Top of Gates (present)	1267.0	80,000*	5,700*
Top of Conservation Pool	1266.0	68,600	5,300
Winter Drawdown Minimum Pool (March 1st)	1262.5	49,800*	5,200*
Top of Desired Fish and Wildlife Pool	1257.0	28,000	1,500
Top of Service Spillway Crest	1252.0	18,000*	2,250*
Top of Dead Pool and Outlet Works	1238.0	1,200	350*

Outlet Works Capacity @ 1266.0 feet = 22,000 cfs @ 1273.2 feet = 43,100 cfs	* Estimated from original area-capacity curve
Downstream Channel Capacity = 2,400 cfs	

Figure 5
BALDHILL DAM / LAKE ASHTABULA RESERVOIR
Storage Configuration

```
Top of Dam = 1278.5 feet          158,000 AF
      ------------------------------------------
                                              |                                                                  |
                                              |                                                                  |
                                              |                                                                  |
Top of Flood = 1273.2 feet                    |                                                                  |
                                              |                                                                  |
Top of Gates                                  |                               Overflow Spillway Crest = 1271.0   |
      Proposed = 1271 feet                    |________________________-----------------------------------------------------|
                                              |                         |<-------  800 feet ------------------------------>
Top of Gates                                  |                         |
      Present =  1267 feet                    |-------------------------------|
Top of Conservation = 1266 feet               | Presently are 3 taintor |
                                              | gates 15 feet high by   |
                                              | 40 feet long            |
Top of desired F&WL Pool
                       = 1257 feet            |                         |
                                              |                         |
Service Spillway Crest = 1252                 |--------------------------------|
                                              |<------- 120 feet ---------->|

Top of Dead Pool and Outlet Works = 1238 feet
```

Notes:
1. Reservoir is formed by an earth filled dam, 1,650 feet long; drainage area is 7,470 mi² with approximately 5,560 mi² noncontributing;
2. Storage began July 30, 1949; dam completed September 1949 (USGS, Water Data Report ND-96-1).

Demands on the Lake Ashtabula water supply were based on actual storage permits. These permits were adjusted for actual demand conditions in 1994 and 2050. All priority dates and uses along the Sheyenne and Red Rivers were considered before withdrawing water from Lake Ashtabula. It should be noted that Lake Ashtabula shortage computations were performed in two phases for the cities of Fargo, Grand Forks, Valley City, West Fargo, and Lisbon. The first phase was based on model computations using actual permit approval dates of each city. The second and final phase of computation was based on a reallocation of these shortages based on the city storage allocations as part of the Thomas-Acker Plan (as described in a memorandum dated November 27, 1992, from the Director of the Hydrology Division to a Water Resource Engineer assigned to the North Dakota State Water Commission – see Attachment I). As a result, under the final redistribution, the municipalities with storage rights from Lake Ashtabula were assumed to be entitled to their permitted amount without regard to a priority or permit date. Therefore, any shortage derived from the reservoir was distributed among the permitted cities based on their original permitted proportion of the allocated reservoir storage. The final distribution of the total Lake Ashtabula storage shortage was distributed among the cities as follows:

Fargo	56.1 percent
Grand Forks	31.3 percent
Valley City	10.5 percent
West Fargo	1.5 percent
Lisbon	0.6 percent

A simplified computation of redistribution of shortages for the five cities (Fargo, West Fargo, Grand Forks, Valley City, and Lisbon) receiving water from Lake Ashtabula was used in Phase I, Part A. However, with the increase in shortages expected as a result of changes in Phase II, this method of computation was deemed inadequate. As a result, an attempt to make the model more accurate and automatic for distributing shortages as per the Thomas-Acker Plan was initiated. Resultant model changes included splitting up the Lake Ashtabula contents, inflows, releases, and evaporation into six different operations. Lake Ashtabula was reorganized into 6 proportionally scaled down reservoirs that would operate to mimic the allocation allotted to each city under the plan. The 6th reservoir was set up to mimic additional storage for use by downstream entities as part of the Lake Ashtabula expansion option. Although not a perfect representation of shortage "faulting" of one or more city in one year that would affect the next year's operation, this methodology is a great improvement over Phase I, Part A computations. Tables 12 and 13 illustrate the area-capacity relationships of each city's allocation reservoir as used in the hydrologic model for both present and future conditions respectively.

In addition to the M&I demands on Lake Ashtabula, the model simulations also include an operational release of 13 cfs below Baldhill Dam to meet existing water rights. Further details on the operations can be found in Baldhill Dam and Lake Ashtabula, Sheyenne River, Reservoir Regulation Manual, (Corps 1983, rev.)

Table 12: HYDROSS Model Segregation of Lake Ashtabula Storage 1994 Conditions

Contents

Original 1994 Lake Data (1000s ACFT)	Fargo Split (56.1%) (1000s ACFT)	G Forks Split (31.3%) (1000s ACFT)	V City Split (10.5%) (1000s ACFT)	W Fargo Split (1.5%) (1000s ACFT)	Lisbon Split (0.6%) (1000s ACFT)	Total (Check) (1000s ACFT)
	HYDROSS Segregated Allocation Based on Thomas-Acker Plan					
0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.000	4.488	2.504	0.840	0.120	0.048	8.000
18.000	10.098	5.634	1.890	0.270	0.108	18.000
28.000	15.708	8.764	2.940	0.420	0.168	28.000
38.000	21.318	11.894	3.990	0.570	0.228	38.000
48.000	26.928	15.024	5.040	0.720	0.288	48.000
58.000	32.538	18.154	6.090	0.870	0.348	58.000
68.000	38.148	21.284	7.140	1.020	0.408	68.000
68.200	38.260	21.347	7.161	1.023	0.409	68.200

Surface Area

Original 1994 Lake Data (acres)	Fargo Split (56.1%) (acres)	G Forks Split (31.3%) (acres)	V City Split (10.5%) (acres)	W Fargo Split (1.5%) (acres)	Lisbon Split (0.6%) (acres)	Total (Check) (acres)
	HYDROSS Segregated Allocation Based on Thomas-Acker Plan					
0	0	0	0	0	0	0
1500	842	470	158	23	9	1500
2400	1346	751	252	36	14	2400
3200	1795	1002	336	48	19	3200
3950	2216	1236	415	59	24	3950
4600	2581	1440	483	69	28	4600
5050	2833	1581	530	76	30	5050
5350	3001	1675	562	80	32	5350
5550	3114	1737	583	83	33	5550

Minimum Operations Release (13 cfs)

	Original 1994 Lake Data	Fargo Split (56.1%)	G Forks Split (31.3%)	V City Split (10.5%)	W Fargo Split (1.5%)	Lisbon Split (0.6%)	Total (Check)
		HYDROSS Segregated Allocation Based on Thomas-Acker Plan					
cfs	13.000	7.293	4.069	1.365	0.195	0.078	13.000
acft/day	25.785	14.465	8.071	2.707	0.387	0.155	25.785

Notes:
1. All minimum pools, spillway levels and other operations criteria used in the hydrologic modeling as part of this study were proportioned based on the above data.
2. The above data represents geometrically proportional reservoirs operated to ensure agree upon allocations to cities participating in the Thomas-Acker Plan.
3. Allocation operations criteria based on "shortage causing" cities was beyond the limits of the HYDROSS model. The above represents simulation criteria based on agreed upon allocations of Lake Ashtabula water.

Table 13: HYDROSS Model Segregation of Lake Ashtabula Storage 2050 Conditions

Contents

Original	HYDROSS Segregated Allocation Based on Thomas-Acker Plan					
1994 Lake Data (1000s ACFT)	Fargo Split (56.1%) (1000s ACFT)	G Forks Split (31.3%) (1000s ACFT)	V City Split (10.5%) (1000s ACFT)	W Fargo Split (1.5%) (1000s ACFT)	Lisbon Split (0.6%) (1000s ACFT)	Total (Check) (1000s ACFT)
0.000	0.000	0.000	0.000	0.000	0.000	0.000
5.700	3.198	1.784	0.599	0.086	0.034	5.700
15.700	8.808	4.914	1.649	0.236	0.094	15.700
25.700	14.418	8.044	2.699	0.386	0.154	25.700
35.700	20.028	11.174	3.749	0.536	0.214	35.700
45.700	25.638	14.304	4.799	0.686	0.274	45.700
55.700	31.248	17.434	5.849	0.836	0.334	55.700
59.700	33.492	18.686	6.269	0.896	0.358	59.700
66.600	37.363	20.846	6.993	0.999	0.400	66.600

Surface Area

Original	HYDROSS Segregated Allocation Based on Thomas-Acker Plan					
1994 Lake Data (acres)	Fargo Split (56.1%) (acres)	G Forks Split (31.3%) (acres)	V City Split (10.5%) (acres)	W Fargo Split (1.5%) (acres)	Lisbon Split (0.6%) (acres)	Total (Check) (acres)
0	0	0	0	0	0	0
1500	842	470	158	23	9	1500
2400	1346	751	252	36	14	2400
3200	1795	1002	336	48	19	3200
3950	2216	1236	415	59	24	3950
4600	2581	1440	483	69	28	4600
5050	2833	1581	530	76	30	5050
5350	3001	1675	562	80	32	5350
5550	3114	1737	583	83	33	5550

Minimum Operations Release (13 cfs)

	Original	HYDROSS Segregated Allocation Based on Thomas-Acker Plan					
	1994 Lake Data	Fargo Split (56.1%)	G Forks Split (31.3%)	V City Split (10.5%)	W Fargo Split (1.5%)	Lisbon Split (0.6%)	Total (Check)
cfs	**13.000**	7.293	4.069	1.365	0.195	0.078	13.000
acft/day	**25.785**	14.465	8.071	2.707	0.387	0.155	25.785

Notes:

1. All minimum pools, spillway levels and other operations criteria used in the hydrologic modeling as part of this study were proportioned based on the above data.
2. The above data represents geometrically proportional reservoirs operated to ensure agree upon allocations to cities participating in the Thomas-Acker Plan.
3. Allocation operations criteria based on "shortage causing" cities was beyond the limits of the HYDROSS model. The above represents simulation criteria based on agreed upon allocations of Lake Ashtabula water.

c. Lower Red River Operations

Red River operations mainly consisted of accounting for inflows from tributaries, withdrawals, and return flows. Inflows from the various tributaries were computed as historic natural flows depleted by the demand levels computed by USGS (Guenther et al., 1991; Guenther, 1993).

One of the major diversion areas on the lower Red River encompasses the city of Grand Forks. The estimated flow at the Grand Forks intake is the estimated natural Red River flow that would occur at Grand Forks based on present and future calculated depletions due to upstream demands and the operation of the Sheyenne River including the operation of Lake Ashtabula. It should be noted that Lake Ashtabula operations might result in increases in flow of the Red River in some years and decreases in others depending in part on the monthly change in storage at Lake Ashtabula. Increases in flow occur when water is released for M&I water, and decreases occur due to evaporation and storage of water in the reservoir.

Other major demands considered on the river include the following:

? American Crystal Sugar Company has the number one water right of 1,841 acre-feet on the Red River.

? East Grand Forks demands are satisfied by the Red Lake River before any diversions by the city of Grand Forks are allowed. Grand Forks M&I use of the Red Lake River is limited to 10,500 acre-feet per year in an agreement with the State of Minnesota. To fully use all water, the simulation first uses water from the Red Lake River up to the allowed amount; then, water is taken from the Red River; and, if there are shortages, the demand is placed against Lake Ashtabula.

? Drayton has a water right senior and junior to both Fargo and Grand Forks, so water is bypassed from upstream sources when required. A shortage could occur when the river has low flow as Drayton has no storage allocation at Lake Ashtabula.

d. Red Lake River Operations

The Red Lakes are located on the upper Red Lake River in Minnesota. The lakes are composed of an upper and lower portion and are operated by the Corps. Upper Red Lake has a surface area of 168.5 square miles, a maximum depth of 20 feet, and an average depth of 3 feet. Lower Red Lake has a surface area of 245.6 square miles, a maximum depth of 35 feet, and an average depth of 18 feet.

Until the early 1930s, the Red Lake River was uncontrolled. The Bureau of Indian Affairs (BIA) constructed the original control structure in 1931. Modifications to the structure in the river channel downstream later took place and were completed in 1951. At this time, BIA turned control over to the Corps.

Currently, the operation of Red Lake is in accordance with an agreement between the Red Lake Band of Chippewa Indians and the Corps. When the level of the Red Lake is between 1173.5 and 1172.0, the outflow is regulated to not exceed 50,000 acre-feet annually. When the lake level is below the minimum conservation pool elevation of 1171.0, the maximum release from the reservoir is 15 cfs and the minimum is 5 cfs, as specified in the agreement.

For this study, the depleted natural flows computed by Guenther in the 1991 and 1993 USGS studies were used as inflow to the Red River portion of the HYDROSS model. The level of depletions used was 1984. If further studies are warranted, it is suggested that full detail of the Red Lake River system be included in the model.

5. Channel Losses

Generally, the detailed computation of channel losses in the Red and Sheyenne River systems due to bank storage, infiltration, and evaporation is beyond the scope of this study. The HYDROSS model does have the capability to include channel losses as part of its suite of variables. If more detailed studies are warranted, more detail could be added to the model.

For this study, it is assumed that much of the natural channel loss was already accounted for in the computation of natural flows by USGS (Guenther et al., 1991; Guenther, 1993). However, it is understood that additional losses could occur to release water added to the reach of the Sheyenne River by Lake Ashtabula. Since little information exists on this subject, many of the assumptions used were based on professional judgment. The USGS report did estimate losses on the Sheyenne River—these loss estimates are the basis for the assumptions used in this study. The USGS report concluded that the worst-case evaporation loss from the headwaters to the mouth of the Sheyenne River based on a 100-cfs project delivery release was as follows in Table 14.

Table 14: Maximum Loss Estimate on the Sheyenne River Based on a 100 cfs Project Delivery

Month	Year	Loss (cfs)
January	1963	1.4
February	1934	2.1
March	1958	4.5
April	1980	12.6
May	1980	45.6
June	1974	38.8
July	1936	49.4
August	1976	51.0
September	1948	40.2
October	1945	17.9
November	1939	6.2
December	1939	1.6

Since Lake Ashtabula is located approximately 48 percent of the way from the head waters to the mouth (total channel length = 512 miles; Guenther, 1993) (Baldhill Dam location = mile 269.8) (USGS streamgauge records for gauge 05058000), the loss rate based on channel length for the above worst-case months would be split 48 and 52 percent of the total from the headwaters to Lake Ashtabula and from Lake Ashtabula to the mouth respectively. Table 15 lists a breakdown the loss estimates for the Sheyenne River (based on a 100-cfs delivery release):

Table 15: Estimated Maximum Losses on the Sheyenne River from The Headwaters to its Mouth

Month	Year Of Maximum Loss	Total loss (cfs)	Loss from Headwaters to Lake Ashtabula (cfs) (48%)	Loss from Ashtabula to mouth (cfs) (52%)
January	1963	1.4	0.7	0.7
February	1934	2.1	1.1	1.0
March	1958	4.5	2.2	2.3
April	1980	12.6	6.0	6.6
May	1980	45.6	21.9	23.7
June	1974	38.8	18.6	20.2
July	1936	49.4	23.7	25.7
August	1976	51.0	24.5	26.5
September	1948	40.2	19.3	20.9
October	1945	17.9	8.6	9.3
November	1939	6.2	3.0	3.2
December	1939	1.6	0.8	0.8

It should be stressed that these were considered the worst-case months for the period of record. No data were presented for other years or conditions. As a result, it was decided to develop generalized loss rate categories for wet, normal, and dry conditions. This was accomplished by examining the computed net evaporation (recorded precipitation minus recorded evaporation corrected for Class A evaporation pan effects) and grouping the annual net evaporation into wet, normal, and dry condition categories. A frequency analysis of annual net evaporation for Lake Ashtabula was done with computed net evaporation used in the model. Years with an annual net evaporation rate below the 33rd percentile were considered wet years, years with an annual net evaporation rate between the 33rd and 67th percentile were considered normal years, and years above the 67th percentile were considered dry years. Wet year net evaporation losses were designated at 25 percent of the maximum loss for the reach between Lake Ashtabula and the mouth of the Sheyenne River based on USGS data. Normal years were designated at 50 percent, and dry years were designated to be 75 percent of the maximum loss. Resulting losses were then grouped as displayed in the following table. These results were entered into the HYDROSS model for each run. Since these amounts were based on a 100-cfs initial delivery, the model subtracted the monthly amount of the release in terms of a percent of the project delivery on the river. To remain conservative, the losses were removed just downstream of Baldhill Dam.

If future, more detailed studies are warranted, it is suggested that the above assumptions and methods used in the HYDROSS model for this study be re-examined and modified as new information becomes available. Tables 16 and 17 list a breakdown of the estimated normal, wet, and dry year losses for the Sheyenne River both upstream and downstream of Lake Ashtabula.

Table 16: Estimated Wet, Dry, and Average Year Losses on the Sheyenne River from its Headwaters to its Inflow Point to Lake Ashtabula

Month	Maximum loss from Headwaters to Lake Ashtabula (cfs)[1]	Wet year loss (cfs)	Normal Year loss (cfs)	Dry Year loss (cfs)
		Or percent of delivery[2]		
January	0.7	0.2	0.4	0.5
February	1.0	0.3	0.6	0.8
March	2.2	0.6	1.2	1.7
April	6.0	1.7	3.3	5.0
May	21.9	5.9	11.9	17.8
June	18.6	5.1	10.1	15.2
July	23.7	6.4	12.9	19.3
August	24.5	6.6	13.3	19.9
September	19.3	5.2	10.5	15.7
October	8.6	2.3	4.7	7.0
November	3.0	0.8	1.6	2.4
December	0.8	0.2	0.4	0.6

[1] Based on USGS estimates.
[2] Since the above figures are based on losses for a 100-cfs project release, they are also considered percent losses based on volume of other deliveries.

Table 17: Estimated Wet, Dry, and Average Year Losses on The Sheyenne River from Lake Ashtabula to its Mouth

Month	Maximum loss from Ashtabula to mouth (cfs)[1]	Wet year loss (cfs)	Normal Year loss (cfs)	Dry Year loss (cfs)
		Or percent of delivery[2]		
January	0.7	0.2	0.4	0.5
February	1.1	0.3	0.6	0.8
March	2.3	0.6	1.2	1.7
April	6.6	1.7	3.3	5.0
May	23.7	5.9	11.9	17.8
June	20.2	5.1	10.1	15.2
July	25.7	6.4	12.9	19.3
August	26.5	6.6	13.3	19.9
September	20.9	5.2	10.5	15.7
October	9.3	2.3	4.7	7.0
November	3.2	0.8	1.6	2.4
December	0.8	0.2	0.4	0.6

[1] Based on USGS estimates.
[2] Since the above figures are based on losses for a 100-cfs project release, they are also considered percent losses based on volume of other deliveries.

6. Irrigation

Because this study focused on municipal, rural, and industrial uses, no attempt to determine future irrigation water use was undertaken. Available water right data were used to develop a "present condition" level of irrigation use. This level was maintained in future scenarios and therefore may not reflect any irrigation practice changes that could take place in the year 2050. Assumptions used in the development of the irrigation component of the model included the following.

? Diversion levels were set at full existing water right acreage. This meant that irrigators were entitled to irrigate their full-allotted acreage at 1996 levels for present and future condition model simulations. Irrigators could, however, be faced with shortages under low flow conditions as water is made available to senior water right holders. Total appropriated irrigation surface water for the Red and Sheyenne Rivers was estimated at 9,150 and 5,248.2 acre-feet, respectively.

? Irrigation diversion rates were subject to a standard crop pattern (wheat, corn, and potatoes evenly distributed over each acre) and the prevailing climatological conditions. Crop irrigation requirements were computed for each acre based on the Modified Blaney-Criddle computational method. This method utilizes precipitation, evaporation, temperature, and frost data to determine monthly crop water needs. (Attachment F contains results of the modified Blaney-Criddle estimates of Crop Irrigation Requirements).

? Since most irrigators use sprinklers in the study area, a water conveyance efficiency of 90 percent and an onsite efficiency of 85 percent were assumed.

? Return flows from irrigation were considered minimal due to the high efficiency of sprinklers and losses due to evaporation.